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TITANIUM AND ITS ALLOYS

—Materials & Methods Manual No. 82

MAY
1952

THE MAGAZINE OF

MATERIALS ENGINEERING

DEVOTED TO THE MATERIALS PROBLEMS OF PRODUCT DESIGN AND MANUFACTURE

Materials & Methods®

THE MAGAZINE OF MATERIALS ENGINEERING • *VOL. 35, NO. 5* • *MAY, 1952*

Feature Articles

Materials & Methods Manual No. 82

Engineering File Facts

Departments

Published monthly by Reinhold Publishing Corporation, 330 West 42nd Street, New York 36, N.Y.
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The Materials Outlook

The Cincinnati Milling Machine Co. is using radioactive tracers to study tool wear. Tools are put into reactors and made radioactive. The tools are then used to cut metal for a few seconds, and the chips are tested for radioactivity. Researchers say that 90% of the tool wear appears in the chips. They can get accurate measurements in a few days by the new method. The same results would take six months with a microscope.

Three 24,000,000-v betatrons, the first ever built for industrial operation, are now being used in eastern and midwestern steel foundries to help speed the production of vital armor steel castings required in the Army's tank program. Powerful enough to penetrate 7 to 9 in. of armor steel in little more than a minute, the x-ray giants greatly speed and improve inspection techniques formerly requiring hours and days in some cases. Previously used only in physics laboratories in atom-smashing experiments, for medical research, and in cosmic ray studies, the betatron now is one of the most advanced tools for nondestructive testing of heavy steel castings. Applied to armor production, it permits fast, positive inspection and quality control procedures, providing sharp x-ray film records through metal sections up to 24 in. in thickness.

The Atlantic Refining Co. has developed a new low penetration, high softening point (165 to 185 F) asphalt resin. Suggested applications of the low cost, low oil content resin include adhesives, battery boxes and rubber compounding . . . . Another resin, with a softening point of 300 F, is under development. The applications will be in molded products, paints, varnishes and rubber compounds.

Quartz paper, developed for the Naval Research Laboratory, can be manufactured cheaply from abundant domestic sources. It can be substituted for higher-cost asbestos insulation material and withstands temperatures up to 3000 F, as compared to 1000 F for asbestos. Since quartz paper is boron-free, it can be used as insulation in components subject to atomic radiation, and in nuclear energy powerplants. The methods of making the quartz fibers was developed by Glass Fibers, Inc.

Glass-reinforced, thermosetting plastic tubing is now in continuous production in commercial quantities. Standard sizes range from 4 to 10 in. o.d. Up to 36-in. o.d. is available on special order. The Navy has found polyester tubing a good substitute for copper-nickel and brass pipe on ships. Applications are expected in housings for airborne equipment, oil lines, salt-water piping and electrical conduits.

(Continued on page 4)

The Materials Outlook *(continued)*

A report from the Engineer Laboratories at Fort Belvoir indicates that bridges have undergone significant development, with greatly increased live load strength and wider roadways. Experiment with wood, aluminum and plastics has still turned up nothing better than low alloy steel.

The Goodyear Tire & Rubber Co. has developed a new synthetic rubber compound for roads. The compound is a free-flowing powder that is easy to handle and mixes freely with asphalt. Tests show that 1.5 to 2% of this rubber added to the weight of the asphalt is as effective as a 5% conventional rubber-asphalt mixture in resisting the stripping action of water and frost. This advantage is credited to the fine particle size of the rubber and its ease of dispersion in the asphalt.

A new development in the production of oil-extended synthetic rubber (25 parts of processing oil added to 100 parts of butadiene-styrene) means lower cost rubber for tires. A 50% increase in the amount of extending oil has been found possible with no impairment of quality. Now 137.5 lb of rubber can be made for the price of 100 lb of conventional cold rubber, plus the cost of the extending oil. The new product shows tread wear equal or superior to that of standard cold or natural rubber. The heat build-up is substantially less.

Scrap is where you find it. At Aberdeen Proving Grounds, the Army is cutting up captured enemy tanks and other foreign weapons, as well as obsolete and worn-out U. S. military items. Over 3000 tons of scrap have been shipped so far, including 20 Russian tanks. Project should produce a total of 5000 tons when completed . . . . Navy reports that since 1948, 10,000 tons of lead have been salvaged, and since 1951, 7,487,501 lb of copper and copper-base alloy. Jet engine overhaul and repair at Naval Air Stations has resulted in the recovery of 200 tons of super-alloys containing cobalt, columbium, molybdenum, nickel and tungsten.

"Too much 'telescopic vision' is causing us to lose focus of the over-all copper situation. Too many persons are venturing appraisals after studying only isolated aspects", reports James T. Duffy, Jr., president of The Riverside Metal Co. "The day is not too far away when we will have copper running out of our ears."

Production Notes: British scientists expect to get plastic airplane bodies and wings into the air by 1955 . . . . Researchers at Battelle Memorial Institute have electroformed aluminum waveguides with twists, bends and tapers. The process points the way to the use of electrodeposited aluminum as an anti-corrosion coating . . . . Lithium aluminum hydride is now available for commercial consumption, free of any use royalties.

See page 6 for "Materials Control Orders"

Materials Control Orders

A summary highlighting actions of the NPA affecting engineering materials during the period from Mar. 11, 1952 through Apr. 10, 1952.

● **CONTROLLED MATERIALS PLAN**

Reg. 1, Reg. 3—Effective immediately, priority ratings identified by the CMP symbols A, B, C, E and Z2 may be passed down the entire chain of procurement and thus place needed materials and parts on the same level of preference as the end product.

Reg. 1, Dir. 9—Converts ACM orders for non-nickel bearing stainless steel, which were outstanding when the steel was decontrolled, to delivery orders bearing a DO rating.

Reg. 4—An amendment permits users of controlled materials to receive orders from distributors 15 days before the quarter for which the allotment is valid.

Reg. 5—An amendment permits printers, publishers and manufacturers of footwear to apply MRO rating to delivery orders for certain types of wire products. Application of DO-MRO priority ratings to obtain printing plates is prohibited.

Anticipated Changes:
Reg. 2—Inventory limitations of all steel products will be raised from 45 to 60 days in the near future.

● **ALUMINUM (Orders M-26, M-27, M-67)**

An amendment to M-67 places aluminum foil under a two-level limitation system to give preferential treatment in the filling of orders for essential uses when a converter's allotted supply is insufficient to meet all orders.

Anticipated Changes: A proposed amendment to M-26 will delete from the order all restrictions on the sale, delivery and use of aluminum closures and closure liners. The quantity of aluminum used for closures would be controlled by CMP allotments to closure manufacturers. Restrictions on the use of aluminum for collapsible tubes would be removed under a proposed amendment to M-27.

● **CADMIUM (Order M-19)**

An amendment relaxes controls on cadmium to permit unrestricted use in items or processes specifically defined and to fill orders bearing the ratings A, B, C, E and Z2.

● **COPPER (Order M-80)**

An amendment increases the number of products in which the use of nickel silver is prohibited.

● **INDUSTRIAL DIAMONDS (Order M-102, M-103)**

Order M-102 provides a mandatory monthly reporting procedure covering inventories, receipts, sales, consumption and reclaimed quantities of crushing bort and diamond powder for all transactions involving more than 10 carats of these materials per month.

Order M-103 places restrictions on users and manufacturers of diamond grinding wheels.

● **IRON AND STEEL (Orders M-1, M-59, M-80)**

Under a new direction to M-1, operators of wide plate rolling mills are restricted in the acceptance of orders for light-gage carbon steel. The limitation affects carbon steels only and does not apply to stainless steels, full-alloyed plate, plates for pipe, armor plate, circles for heads, or conversion plate products.

Order M-59 controlling the use and inventory of steel strapping is revoked.
An amendment to M-80 increases the number of products in which the use of nickel-bearing stainless steel and high nickel alloy steel is prohibited. The prohibition applies also to clad-steels.

● **NICKEL (Order M-80)**

An amendment eliminates the filing of individual requests for allocations of nickel anodes, salts, chemicals, oxides and catalysts, and permits the supplier to group orders and make a single application to NPA. Another amendment increases the number of products in which the use of nickel-bearing stainless steel, high nickel alloy steel, and nickel silver is prohibited.

● **RUBBER (Order M-2)**

An amendment lifts the restrictions on the manufacture of white side wall tires; increases the percentage of natural rubber which can be used in certain products; permits private importation of dry natural rubber without license but prohibits similar importation of natural rubber latex.

● **TIN (Order M-25)**

An amendment makes available 25,000 tons of tin mill plate for the remainder of the present quarter and 68,000 tons for the second quarter; allows canners and packers to use any quantity of secondary tin mill plate without charging the material to quotas; retains restrictions on the quality of prime plate and sets quotas; defines tin plate; requires can manufacturers to offer, on a pro-rate basis, cans made from any part of the secondary tin mill allotment.

● **ZINC (Orders M-9, M-15, M-37)**

Revised order M-9 incorporates the use limitations of M-15 and the restrictions on scrap contained in M-37; permits quarterly as well as monthly allocation of zinc. Orders M-15 and M-37 are revoked.

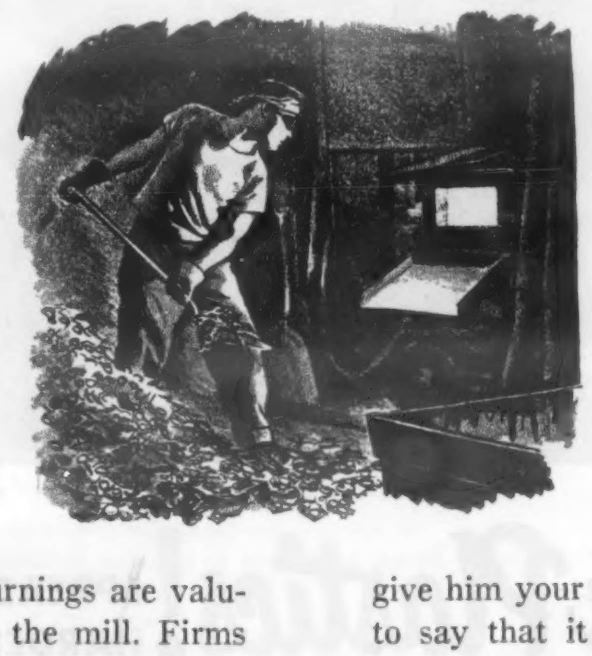
● **NPA REGULATIONS**

Reg. 1—An amendment removes inventory control from 25 chemicals and increases inventory limitation from 45 to 60 days on several other commodities. Certain materials which were placed under control of CMP Reg. 2 were deleted from the inventory control provisions of Reg. 1.

BUSINESS IN MOTION

To our Colleagues in American Business . . .

For several years this space has been used to tell how Revere has collaborated with its customers, to mutual benefit. Now we want to talk about the way our customers can help us, again to mutual benefit. The subject is scrap. This is so important that a goodly number of Revere men, salesmen and others, have been assigned to urge customers to ship back to our mills the scrap generated from our mill products, such as sheet and strip, rod and bar, tube, plate, and so on. Probably few people realize it, but the copper and brass industry obtains about 30% of its metal requirements from scrap. In these days when copper is in such short supply, the importance of adequate supplies of scrap is greater than ever. We need scrap, our industry needs scrap, our country needs it promptly.



Scrap comes from many different sources, and in varying amounts. A company making screw-machine products may find that the finished parts weigh only about 50% as much as the original bar or rod. The turnings are valuable, and should be sold back to the mill. Firms who stamp parts out of strip have been materially helped in many cases by the Revere Technical Advisory Service, which delights in working out specifications as to dimensions in order to minimize the weight of trimmings; nevertheless, such manufacturing operations inevitably produce scrap. Revere needs it. Only by obtaining scrap can Revere, along with the other companies in the copper and brass business, do the utmost possible in filling orders. You see, scrap helps us help you.

In seeking copper and brass scrap we cannot appeal to the general public, nor, for that matter, to the small businesses, important though they are, which have only a few hundred pounds or so to dispose of at a time. Scrap in small amounts is taken by dealers, who perform a valuable service in collecting and sorting it, and making it available in large quantities to the mills. Revere, which ships large tonnages of mill products to important manufacturers, seeks from them in return the scrap that is generated, which runs into big figures of segregated or classified scrap, ready to be melted down and processed so that more tons of finished mill products can be provided.

So Revere, in your own interest, urges you to give some extra thought to the matter of scrap. The more you can help us in this respect, the more we can help you. When a Revere salesman calls and inquires about scrap, may we ask you to give him your cooperation? In fact, we would like to say that it would be in your own interest to give special thought at this time to all kinds of scrap. No matter what materials you buy, the chances are that some portions of them, whether trimmings or rejects, do not find their way into your finished products. Let's all see that everything that can be re-used or re-processed is turned back quickly into the appropriate channels and thus returned to our national sources of supply, for the protection of us all.

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Electroplaters Plan Industrial Finishing Show

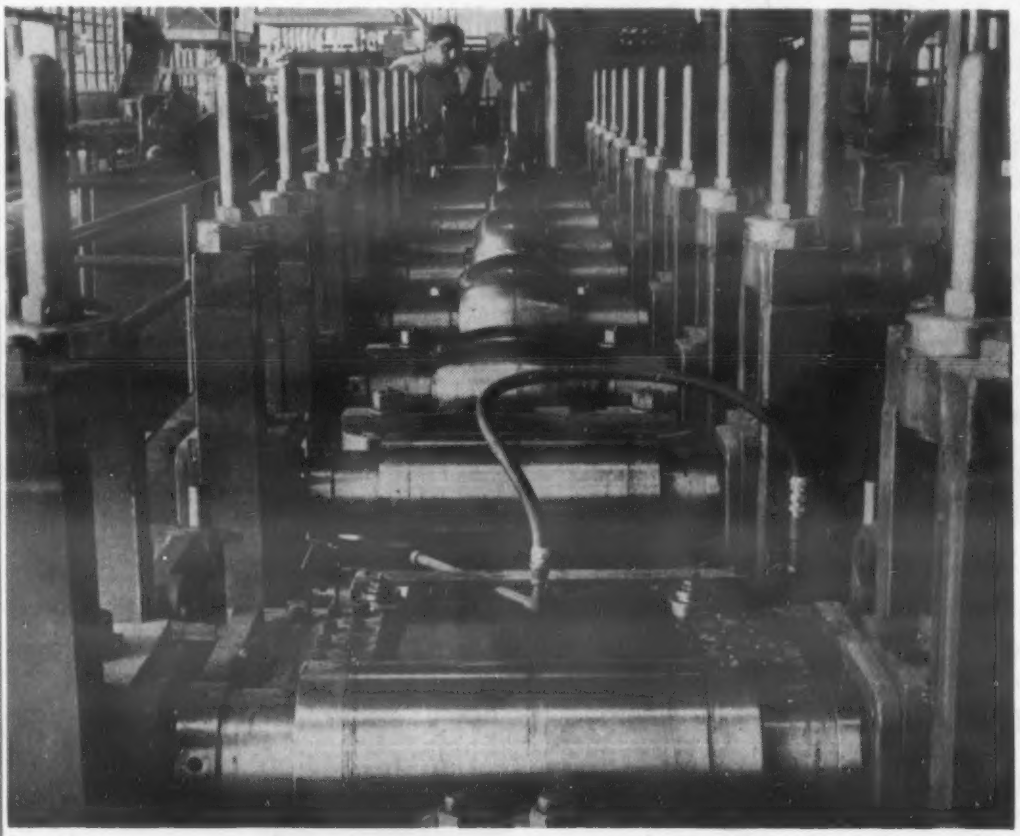
The Industrial Finishing Exposition will be held in Chicago June 16-20 under the sponsorship of the American Electroplaters' Society. More than one-third of the exhibit space at Chicago's International Amphitheater has been reserved by exhibitors. Products and services in electroplating and 15 allied fields will be displayed. The educational sessions of the Annual Convention of the American Electroplaters' Society will be held concurrently.

The scope of the exhibits has been enlarged this year to cover abrasives, automotive plant transportation, basic chemicals and metals, industrial tapes, materials-handling equipment, polishing and buffing equipment and supplies, testing instruments, and publications dealing with metal finishing.

Men of outstanding ability and reputation have been invited to deliver papers at the educational sessions. Among the authors there will be Fred Brune, Dr. Russel Harr, W. S. Morrison and L. Gilbert, Myron Ceresa, L. A. Danse, Fred Keller, Harold Faint, Dr. Harold Wiesner, Frank Savage, W. L. Pinner and Dr. W. R. Meyer.

The subjects covered will include the following: The plating department of Western Electric Co.'s Indianapolis plant; plastics in the plating room; substitute finishes; hard coatings on aluminum; plating of heavy rhodium coatings; the effect of mechanical abrasive-grain polishing on the corrosion resistance of subsequent coatings; and black nickel coatings. A movie will feature a visit to the Westinghouse Electric Corp.'s plating research laboratory. Another session will be devoted to reports from the American Electroplaters' Society Research Committee.

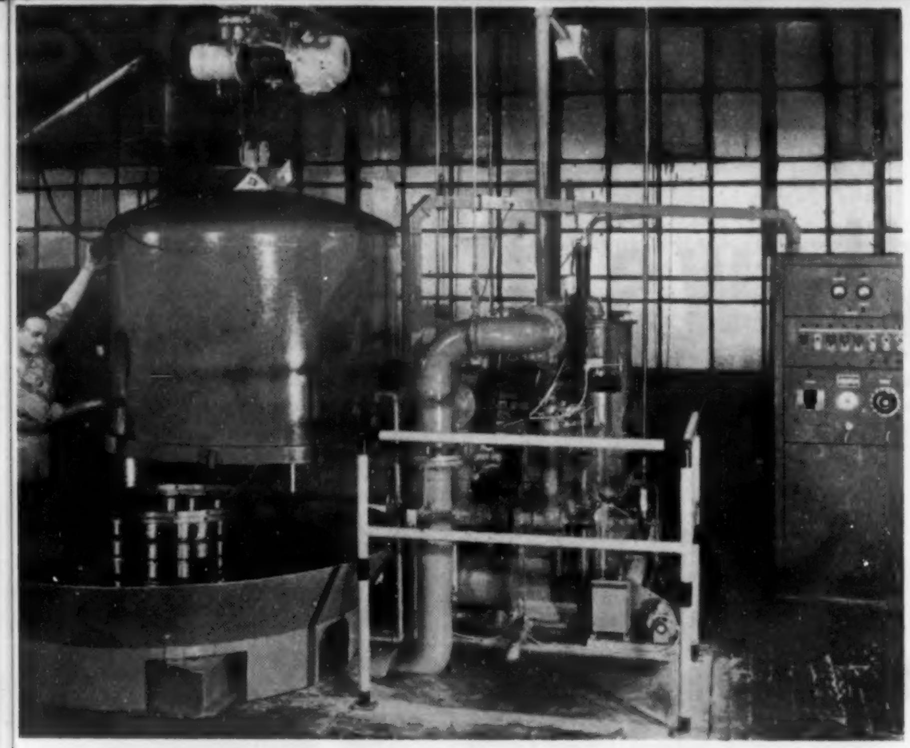
The Conrad Hilton Hotel (largest hotel in the world) will serve as the headquarters of the American Electroplaters' Society Convention. The educational sessions will be held at the Stock Yard Inn. Dual sessions will be held on Monday afternoon, June 16th.



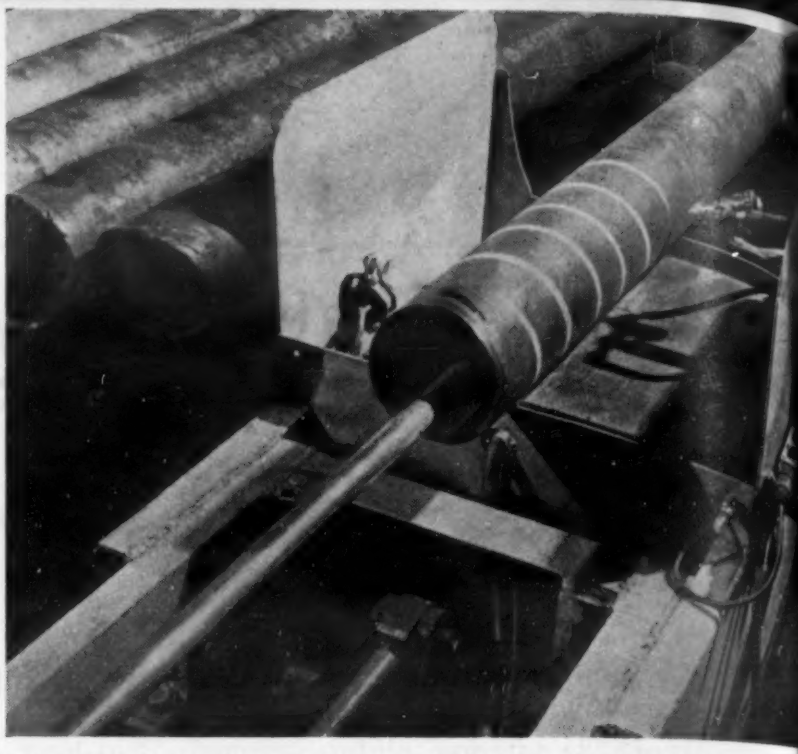
Ford Opens High-Speed Tube Processing Operation

After nearly three years of engineering research and planning, Ford Motor Co. has completed two modern steel tube processing operations which are producing 180 ft of tubing a min. Designed for quick conversion to defense production of welded tubing up to 5-in. dia, the mills are located at the company's Mound Road Plant, near Detroit. One is nearly 400 ft long and turns out tubing for axle housings at a rate of 75 ft per min. The other, 175 ft long, is producing 105 ft of tubing a min for driveshaft assemblies.

The manufacturing procedure of both mills is approximately the same and begins with the automatic unwinding of coiled steel from huge drums. Steel stock enters the loading end of the mill and is gradually formed into tubular shape by a series of parallel rollers. The tube is then welded automatically and the flash removed. Following this, the tube stock is cut to desired length by a process that virtually eliminates waste. Tube stock then is moved automatically to annealing furnaces and transported to other manufacturing buildings to be processed into rear-axle and driveshaft assemblies.



Timken Roller Bearing Co. removes moisture from bearings without corrosion. The bearings enter the 0.005-mm mercury vacuum drier at 130 F. There is no external heat source.



This x-ray device determines the wall thickness of steel. Paint automatically sprays on under-size areas. The pipe is made by the National Supply Co.

Strong Metal-to-Ceramic Bonding Technique Developed

A novel brazing technique which produces strong bonds between metals and nonmetals is described in a report now available to the general public from the Library of Congress. The report, "Metal to Nonmetallic Brazing," prepared by scientists at MIT working on a joint Signal Corps-Air Force-Navy project, summarizes the results of a series of experiments on the brazing of both metals and nonmetallic materials with active metals such as titanium, zirconium, columbium and tantalum.

This brazing technique has been carried out in controlled atmospheres and vacuum with the use of fluxes. The experiments described are of an exploratory nature, with little emphasis on the development of techniques for special applications. The method has been used in brazing a wide variety of materials, *i.e.,* diamonds, sapphires, carbides, various ceramics, refractory oxides, glass, quartz, stainless steel and chromium-iron-type alloys. The active metals used have the interesting property of wetting both metals and nonmetallic materials equally well, and producing exceptionally strong bonds which, in many cases, exceed the strength of the nonmetallic materials.

Good vacuum seals with glass and ceramic have been prepared by this method. Through the use of brazed ceramics in place of glass, higher bakeout temperatures can be achieved, allowing more rapid outgassing of vacuum apparatus. The applications are not, however, limited to vacuum techniques, but should be useful in the preparation of tools or other devices for which nonmetallic materials are bonded to metal.

Color Film Shows Corrosion in Action

A new, sound color film prepared under the direction of the Corrosion Engineering Section of the International Nickel Co., Inc., was shown for the first time at the annual conference and exhibition of the National Association of Corrosion Engineers at Galveston, Tex.

Entitled "Corrosion in Action", this sound color film shows how corrosion works to cause an annual loss in industry and elsewhere estimated over six billion dollars. It also shows how this damage can be avoided or controlled by various means, such as by the selection of corrosion resistant materials, by the development of new alloys to meet given situations, by the use of electric currents to provide cathodic protection and by other methods.

"Corrosion in Action" was made essentially for technical, educational and industrial groups, though its treatment is such that it can be understood by non-technical audiences. It will be released for use in schools, colleges, industrial plants, and before technical societies. Bookings can be made through the Corrosion Engineering Section, The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

Francis M. Turner

With deep feeling of sorrow the publishers of MATERIALS & METHODS report the death of Francis Mills Turner, vice president of Reinhold Publishing Corp., on the morning of April 3rd. Mr. Turner was instrumental in the founding and development of MATERIALS & METHODS (originally known as *Metals & Alloys)* in 1929, and served as managing editor from 1929 to 1931. He was a nationally prominent figure in the chemical world, as well as in technical book and magazine publishing circles. He was author or co-author of several technical books, and was an active member of many important professional, scientific and technical organizations, including the ASTM, the ACS, the Electrochemical Society, the Society of the Chemical Industry, the New York Academy of Sciences, and the American Ordnance Association.

An additional 26,250 tons of Guatemalan pig lead will be made available to American industry for defense purposes over a five-year period under terms of a contract announced recently.

New Metal-Working Processes and Testing Methods Presented to Tool Engineers

The American Society of Tool Engineers held their industrial exposition in Chicago late in March. A number of papers of interest to materials engineers were presented at technical sessions presented with the show.

Surface Gage

A new device to measure the roughness of finished surfaces was announced by General Motors Research Laboratories. The instrument is called the Surfagage. Reading average roughness to one microinch, the apparatus is rugged enough for inspection service in the plant, and is easily portable. It can be plugged into any 110-v a.c. outlet to provide power. The Surfagage utilizes an unusual type of electronic tube to produce a signal that varies with the motion of the stylus that follows the surface configurations on the piece being examined.

Important in calibrating the device is a set of standards produced in cooperation with the Engineering Div. of Chrysler Corp. The roughness standards were made originally by ruling with a tiny diamond point on metal plates, and replicas of these ruled plates are produced by electrodeposition.

The Surfagage consists of a pickup unit, to be moved over the surface being studied, and a metering unit, on which the roughness is recorded on one of several scales. The pickup unit consists of a diamond stylus ground to a 60-deg point, attached through a viscous coupler to the plate of a special type of electronic tube. As the stylus moves over the work surface, the motion perpendicular to the surface is transmitted through the coupler to the tube plate, and the changes in position of the plate are converted into variations in the signal emitted by the tube. These variatons are recorded on the dial of the metering unit to which the pickup is attached, and can be read directly as microinches of average roughness.

Production Processes

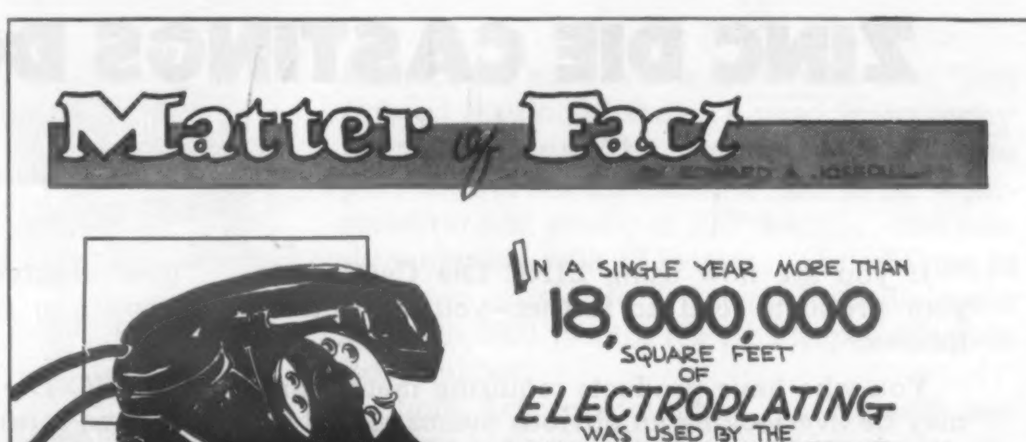
Several papers covered new manufacturing methods and new applications of conventional methods. Trepanning, a hole cutting process, is being used for faster production of gun barrels. The core of the hole is removed in trepanning, and the metal is not all reduced to chips. Trepanning is claimed to be much faster than drilling, especially with larger holes. Another speaker emphasized the production advantages of the broaching process to make teeth on internal gears. Electroforming was said to be used in making many parts for defense equipment. Typical electroformed parts include 6-ft-dia searchlight reflectors, 15-ft radome molds, electroclad bearings, radar feed horns and computing machine components. New developments permit aluminum to be electroformed, speakers said. The effects of uncertain steel quality and the scarcity of deep drawing steel on automobile design were covered in another paper. Next year's cars may not be as streamlined as they could be if the industry does not obtain sufficient high quality steel.

Precision Parts

Two interesting presentations were made on the problems involved in extremely accurate parts. The importance of heat treating techniques to stress relieve these parts and prevent subsequent growth or shrinkage was emphasized by a tool engineer. A gage block at the National Bureau of Standards grew 50 millionths of an inch, for example. A machine tool lead screw that grew 0.0015 in. in a year and then shrank by half that amount was another example of problems encountered. The production processes used in making accurate steel scales were outlined by a Swiss engineer.

A fastener expert explained that a nut will not carry its design load unless it is tight. Thus, a $5/8$-in. nut that is tightened insufficiently may actually be weaker than a correctly assembled $1/2$-in. nut and bolt. Mechanical or power wrenches for uniform tightening were recommended. It was also pointed out that coarse threads are stressed less, are less affected by corrosion, and are easier

(Continued on page 11)



News Digest

continued from page 11

to assemble than fine threads. The increasing use of production line hardness tests was described in another paper. Typical parts checked include armor piercing shells, brass and steel shell cases, and tank, aircraft and rifle parts. Jet engine blades also require precise hardness checks.

Research at NBS Yields Useful Data on Ferrous and Nonferrous Metals

Several reports on research projects conducted at the National Bureau of Standards have been published by the Bureau recently. These reports cover ductile cast iron, low-temperature steel brittleness, stress corrosion, and the determination of copper in iron and steel.

Nodular Cast Iron

A study by Alexander I. Krynitsky and Harry Stern substantially increases available information on the effects of different additives on the formation of nodular graphite. Additives investigated were magnesium, magnesite, iron sulfide, calcium, nickel-chromium-molybdenum and boron. Besides the different additives, the investigation included such variables as composition, melting and pouring temperatures, and cooling rate.

Completely nodular graphite was obtained only in iron containing magnesium in excess of 0.03%. Two types of nodules were observed, radial and structureless, the structureless types frequently having a crystalline core. Results with magnesite, magnesia and the other additives were essentially negative. However, oval or irregular patches of graphite—not true nodules—were observed in iron treated with magnesia, iron sulfide, and boron. Only a few nodules were observed in calcium-treated specimens, but this was probably because of the rather small amount of calcium retained.

The effect of cooling rate on microstructure was determined by casting wedge-shaped bars. The cooling rate, greatest near the apex of the wedge, was observed at intervals

(Continued on page 182)

New Developments in Porcelain and Ceramic Coatings

by PHILIP O'KEEFE, Associate Editor, Materials & Methods

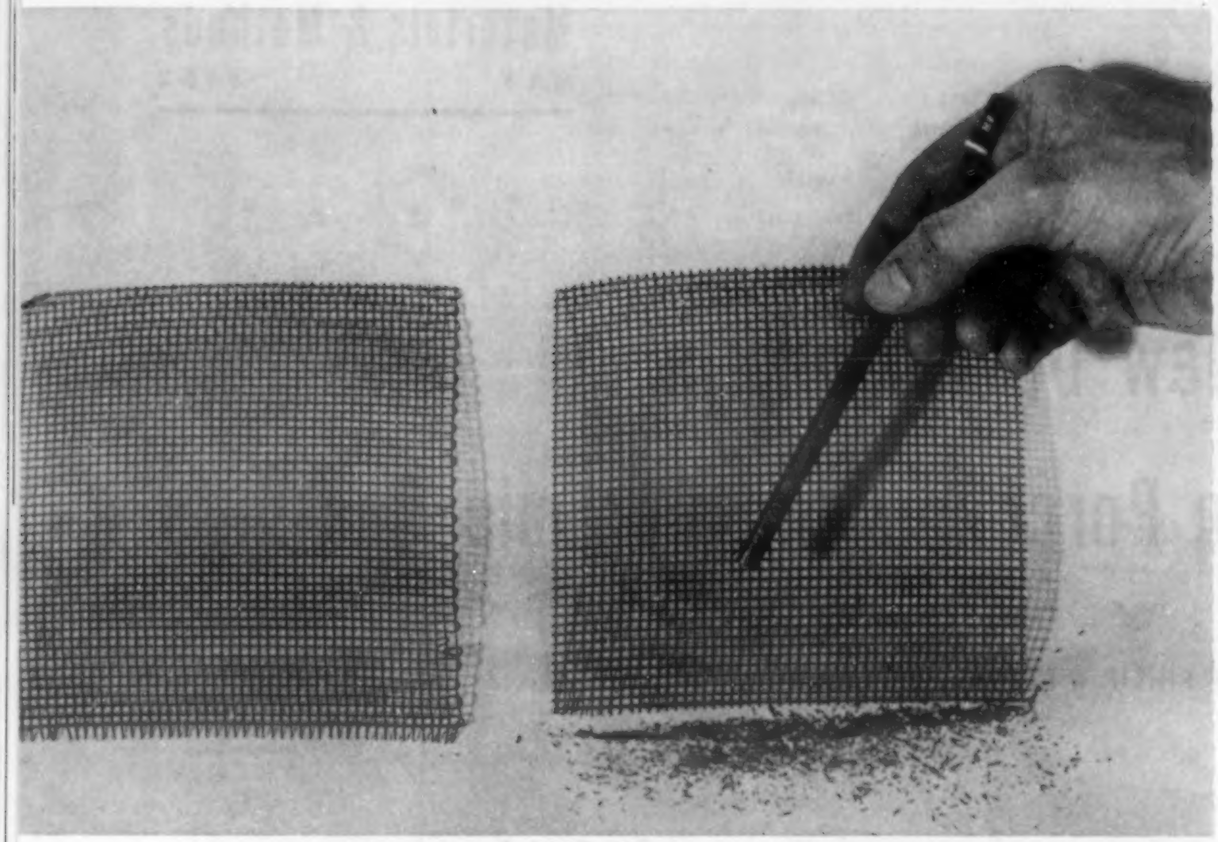
One coat enamels, improved enameling stock, and coatings having improved high temperature, abrasion and impact properties are all stimulating a wider use of porcelain enamels.

● THE TIGHT SUPPLY of alloying elements like nickel and the military necessity of reaching higher temperatures in aircraft engines has put new life in an old art. Ceramic and porcelain enamel coatings were known centuries ago. Since 1940, however, many new materials and techniques have been developed. More durable enamels—coatings that take abrasion, high temperatures, impact and thermal shock—have appeared in the last few years.

One-Coat Enamels

Some of the most important recent developments have been one-coat enamels. These have been made possible by (1) improved base metals for enameling, and (2) enamels of greater hiding power. In the past, a special base coat was needed to assure good bonding to the metal, and additional coats over this base provided the color and protection required. Two or three furnace cycles

Ground coat porcelain enamel is sprayed on range parts after drying in an oven at 350 F. The parts are fired at 1560 F to produce a smooth surface. (Westinghouse Electric Corp.)



The porcelain enamel coated stainless steel screen at the left remained clean after being heated and cooled several times, then soaked at 1700 F for 40 hr. The uncoated screen at the right oxidized badly. (Solar Aircraft Co.)

were required in production, and the enamel coatings often ended up 0.03 in. thick. With the one-coat enamels, thicknesses down to 0.003 in. can be obtained. Thin enamels like these are much more chip-resistant than thicker coatings, and the enameled metal can be formed, drilled and cut without breaking the coating.

There have been two big problems in industrial porcelain enameling—the base metals and the frits themselves. Premium-priced ingot iron, mild steel and cast iron containing no surface defects have been required. Gas-forming elements, especially carbon and hydrogen, could not be tolerated, because they caused blisters and defects in the coating when they were fired. This gas problem was particularly bad with frits with a high vitrifying temperature—in the 1500 F range. The zirconium and antimony type enamels needed a base coat to bind to the surface and protect the metal while firing the cover coats. The covering power or opaqueness of these enamels was also low and they had to be put on thick.

Several lines of development have been followed in solving these problems. Titanium is now being used in steel to bind the carbon, and perhaps the hydrogen too, and prevent gas evolution. These titanium-bearing steels still carry a premium price, though. The use of lower-firing frits, vitrifying around 1350 F, also minimizes gas evolution. The newest trick to beat gas defects when using standard steel, however, is the use of special surface treatments.

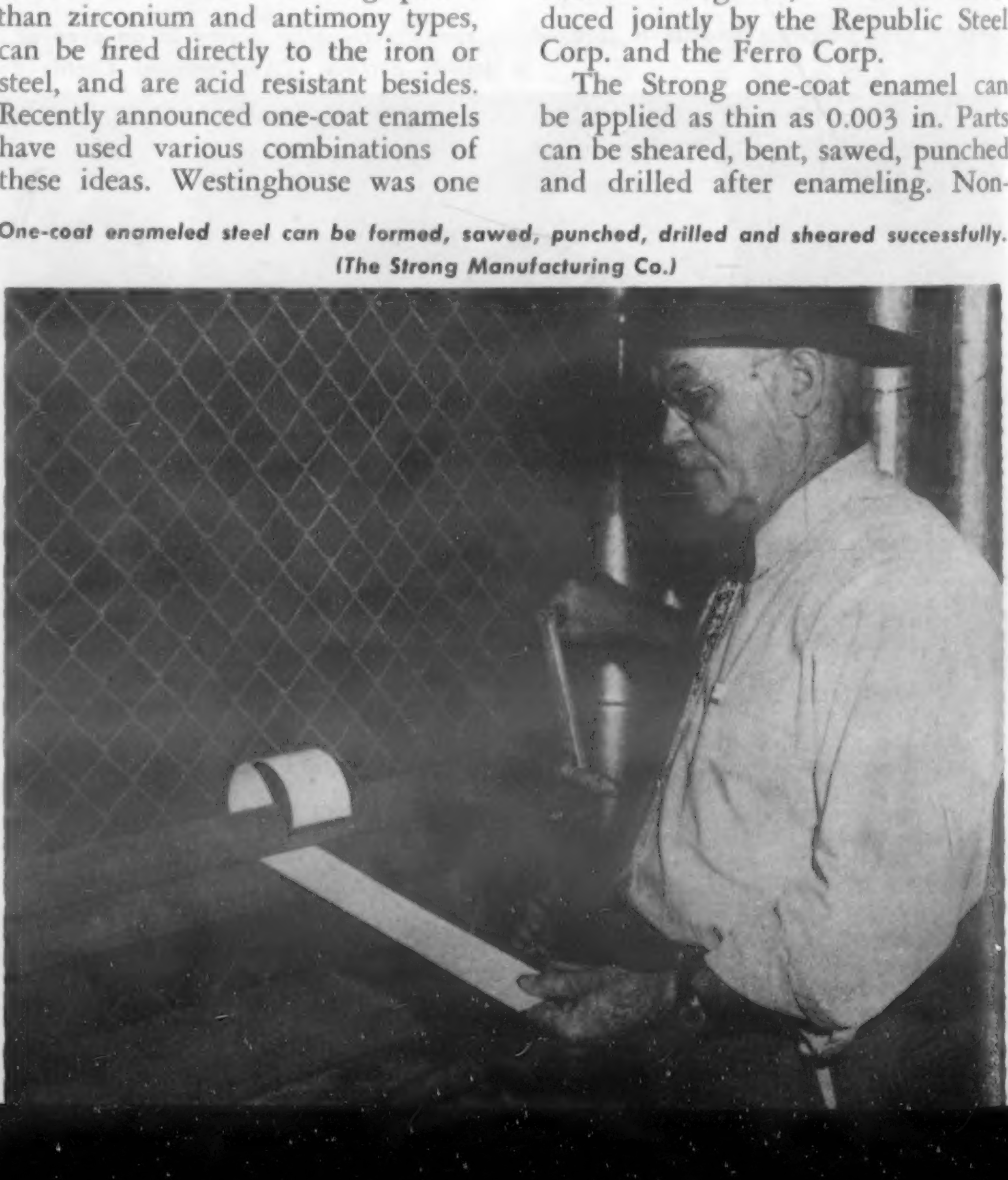
Thin, one-coat enamels have been made practical by titanium type frits, which have better covering power than zirconium and antimony types, can be fired directly to the iron or steel, and are acid resistant besides. Recently announced one-coat enamels have used various combinations of these ideas. Westinghouse was one of the first to come up with a commercial one-coat porcelain enamel process. A high opacity titanium dioxide frit and a titanium stabilized steel are used. The coating thickness is 0.007 in., compared to 0.015 in. for a conventional double coat. Westinghouse is using the new enamel on platforms for kitchen ranges. Resistance to food acids is important here. In service, these platforms are subjected to impact from falling objects and sharp corners. The one-coat enamel is used for its chip resistance. Production economies have also been realized by Westinghouse. The single firing cycle is cheaper than two or more trips through the furnace. Another advantage of the new enamel is that it is less susceptible to damage during shipping of the ranges.

Westinghouse has found some disadvantages, too. The titanium steels cost more than regular steel and are in rather short supply. The one-coat frits also have a narrow bonding range of 30 F. They are fired at 1520 to 1530 F to stay safely within this range. This also brings in the possibility of underfiring at brackets and braces, and some pieces have required redesign before the process could be used.

At least one of these objections—the need for a premium steel—seems to have been mec by two new processes, one developed by The Strong Manufacturing Co., the other introduced jointly by the Republic Steel Corp. and the Ferro Corp.

The Strong one-coat enamel can be applied as thin as 0.003 in. Parts can be sheared, bent, sawed, punched and drilled after enameling. Non-

One-coat enameled steel can be formed, sawed, punched, drilled and sheared successfully. (The Strong Manufacturing Co.)



premium steel is used and the trick is in the metal surface preparation. While any commercial titanium enamel can be used, the softer, lower-firing enamels have been most successful. There is less warping with complicated shapes when low firing temperatures are used. Strong has been producing fluorescent lighting reflectors for Westinghouse by this method on a large volume basis since April 1951.

The Ferro-Republic product is similar—a chip resistant, titania-opacified, one-coat enamel that can be put over non-premium steel. Ferro is more specific about the precoating surface treatment, however. The metal is cleaned and roughened by sand blasting or by a special sharp etching pickling process. The nickel deposition is nongalvanic and no iron goes into solution. This gives a more continuous nickel coat and leaves a rough surface to take the porcelain enamel.

Heat Resistant Coatings

Another field of porcelain enameling has shown activity recently. This is the high temperature field, including finishes vitrifying at temperatures near 2000 F. These finishes are known as *ceramic coatings* rather than *porcelain enamels*. The upper limit of vitrifying temperatures for porcelain enamels is 1600 F.

These ceramic coatings are applied to heat resistant alloys for protection against such forms of deterioration as scaling and intergranular corrosion. Uncoated alloys suffer mostly from the chemical action of hot corrosive gases—particularly oxygen, lead bromide, sulfur compounds and hydrocarbons. The erosive effect of the gases impinging on the alloys at high velocity seems also to be a factor in certain types of service.

Most of the research on ceramic coatings for high temperatures has been done at the National Bureau of Standards. The A-19 coating containing alumina was announced by the Bureau in 1943. This was the first thin coating (0.002 to 0.003 in.) and was designed to protect low carbon steel at 1250 F for long periods in air. The coating was chip and crack resistant because of its thinness. A-19 has been used regularly in military aircraft since 1944. Modified versions have found civilian applications.

In 1945 the Bureau teamed up with the National Advisory Committee for Aeronautics to develop coatings to extend part life and save scarce alloying elements in aircraft engines. The A-417 coating, in commercial production since 1950, has been the most successful coating so far. The A-417 was developed by William H. Harrison, Dwight G. Moore and associates at the NBS. It is a high-barium, alkali-free frit with 30% chromic oxide. The coating is sprayed or dipped on and fired at 1850 F. The result is a smooth, uniform, green-colored finish in controlled thicknesses between 0.001 and 0.002 in. Thus far the coating has been used mainly with Inconel and 19-9DL alloy, but it has also been applied successfully to HS-21, S816 and 18:8. A-417 can probably be used effectively with any of the common heat resisting alloys.

The value of A-417 has been established both by laboratory tests and by substantial service experience. The coating retards carbon absorption from exhaust gases of high fuel-air ratios, corrosion from lead compounds present in the exhaust stream, and oxidation of exterior surfaces in contact with the air. At the same time, it has good resistance to high temperature heat flow; has high resistance to thermal shock; adheres well, even at 1650 F; and covers edges and welds effectively.

In one laboratory test, A-417 coated Inconel was heated 500 hr at 1650 F in air. The coating retained most of its initial properties. The adhesion was almost as good as before heating, although there was some loss of gloss. There was no "burn-off", "copper-heading" or blistering.

For over a year, Inconel heat exchangers used in the exhaust system of a large bomber to supply heated air for de-icing have been A-417 coated in regular production. Uncoated heat-exchanger parts had previously been failing after only a short time under some service conditions, apparently because of intergranular corrosion. Design changes and coating the exchangers with A-417 increased service life many times over. Success of the coating with heat exchangers has led to other exhaust-system applications. Service tests by commercial airlines have shown that life expectancy of exhaust collector parts is increased, and coated exhaust system parts are now being produced in substantial quantity. I-40 gas turbine blades coated with A-417 have also given encouraging results in accelerated laboratory tests, although data are limited. Even at high temperatures, the coating seems notably free from flow due to centrifugal force.

The NBS coating is not the only high temperature ceramic coating in use. Solar Aircraft Co. is testing a formula of their own development with equally attractive potentialities. These coatings are being used in jet combustion chambers to lower the alloy requirements for a given service life.

The new ceramic coatings developed by the National Bureau of Standards have been used to protect airplane engine exhaust systems. (Ryan Aeronautical Co.)

Base of Westinghouse bell type nitriding furnace being loaded with a charge of internal gears. The bell cover is visible in the background.

How to Case Harden Steel by Nitriding

by JOHN L. EVERHART, Associate Editor, Materials & Methods

Proper use of nitriding on suitable steels provides parts with excellent wear resistance and retention of hardness at elevated temperatures.

● THE NITRIDING PROCESS is a means of case-hardening certain alloy steels by treating them with ammonia or other nitrogenous material. The particular advantages of nitriding are: (1) no subsequent treatment is necessary; (2) minimum distortion during treatment; (3) high resistance to wear; (4) retention of hardness at elevated temperatures; (5) improvement of fatigue properties. The principal disadvantages are: (1) the extended time required for obtaining a suitable case; (2) the process is relatively expensive since special equipment is required; (3) special steels are necessary if maximum hardness is to be obtained.

The Process

The nitriding process depends for its effectiveness on the formation of nitrides in the steel by the reaction of nitrogen with certain alloying constituents. There are two basic requirements. A nitride forming element must be present and the nitrogen must be supplied to the surface in atomic form. Ordinary molecular nitrogen will not nitride a steel.

In the original nitriding process, the steel is exposed to gaseous ammonia at a suitable temperature for the formation of the metallic nitrides. The material to be nitrided must be placed in a closed container with means supplied for the continuous circulation of the ammonia. However, no special furnace is needed, although it is necessary that the furnace be capable of maintaining uniform heating conditions for the time required to complete the operation. The temperatures are maintained generally in the range 930 to 1050 F, and the operation requires up to 90 hr for completion. Upon exposure of the steel to ammonia in this temperature range part of the ammonia breaks down into atomic nitrogen and hydrogen, the former attacking the steel to form nitrides while the latter passes from the furnace with the excess ammonia. Usually conditions are adjusted to obtain 30% decomposition of the ammonia. It is agreed generally that the case thus formed consists of two layers. The outer, or "white layer", is composed entirely

of the nitrides of iron and those alloying elements which form nitrides. This layer is usually removed by grinding after nitriding. The inner layer contains precipitated nitrides formed by diffusion inward of the nitrogen from the white layer. Being a diffusion process, the depth of case depends on the time of exposure to the nitrogen. With suitable equipment, this method of nitriding is readily controllable and is the most widely used process at present.

A modification of the process has been developed by Floe for applications where grinding off the white layer is undesirable or impractical. This is a two-stage nitriding cycle in which the ammonia dissociation is held at 20% for a period of 5 to 10 hr at 975 F. The temperature is then increased to 1025 to 1050 F and the ammonia dissociation to 80 to 85%. During the second stage, any white layer which has been formed on the surface is removed by inward diffusion of the nitrogen. Thus, the final case is practically free of a white layer and ready for service immediately. This process is being increasingly employed for such applications as gears where the elimination of a finishing operation reduces the cost greatly.

A second method consists of heating the steel in a suitable salt bath maintained in the same temperature range as that used for gaseous nitriding. Although a number of compositions are in use, they are all variations of the basic mixture of 60% sodium cyanide-40% potassium cyanide. It has been claimed that this procedure is more rapid than gaseous nitriding because of more intimate contact of the nitrogen with the steel. However, this point is somewhat controversial for, being a diffusion process, the rate of penetration is determined by the composition of the steel, and given a sufficient supply of nitrogen at the surface, the rate should be independent of the means of supplying that nitrogen. Be that as it may, the process is less generally applied than the gaseous procedure. It is particularly advantageous for nitriding small lots of material and is frequently used for the application of a thin case on tool steels. Ease of temperature control is another advantage of this process. There are a number of variations of the salt bath process such as, for example, bubbling ammonia into a cyanide bath.

Nitriding Steels

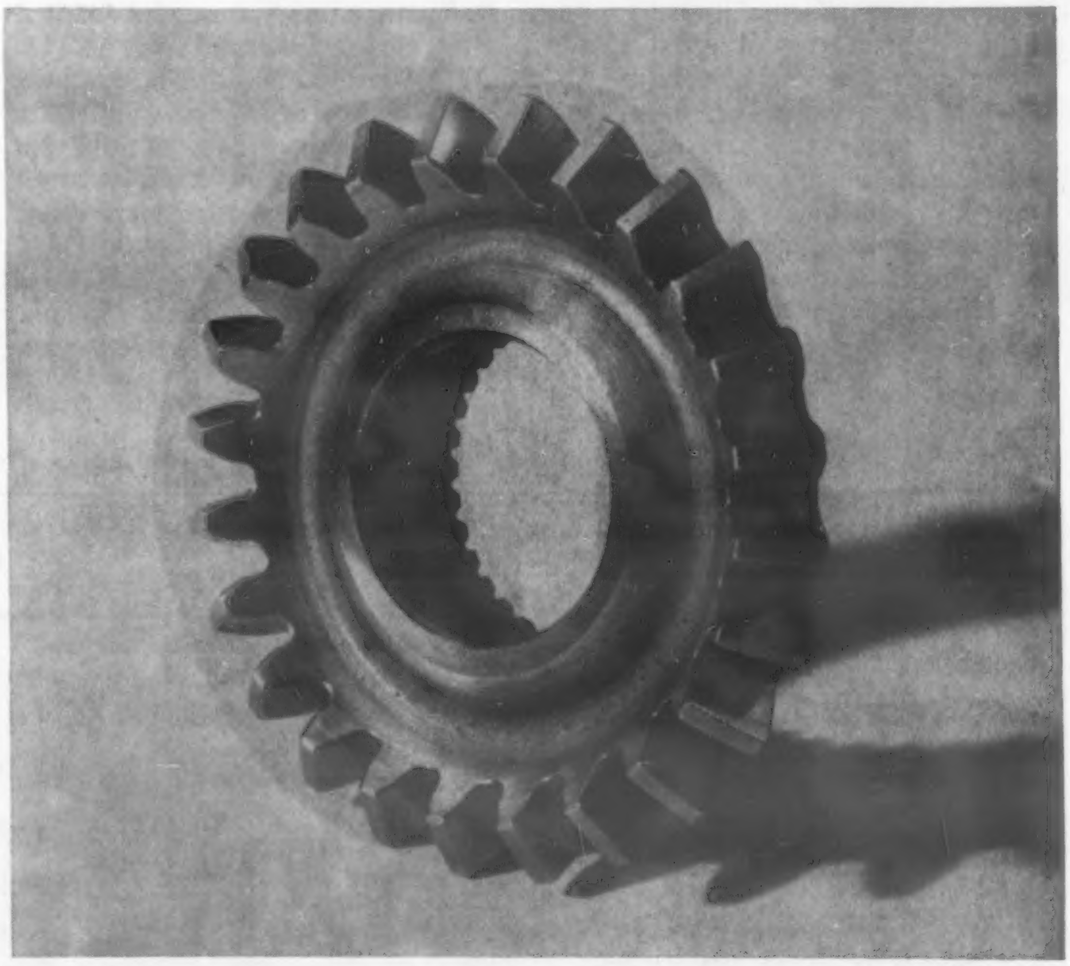
The requirements of steels for nitriding are: (1) suitable alloy constituents, and (2) proper condition. The principal elements which contribute to the formation of useful nitride cases are aluminum, chromium, molybdenum, vanadium, tungsten and titanium. Other elements, such as carbon, silicon and nickel, do not form nitrides but can influence the type of case by obstructing the rate of penetration of the nitrogen and thus reducing the case depth. Carbon can also influence the case by forming carbides with elements such as chromium and removing them from the reaction. The special role of nickel in aluminum-bearing steels will be referred to later. The content of alloying elements is also important in providing suitable core properties.

The hardest cases are obtained with aluminum-bearing steels, and a special class of steels, the Nitralloys, which contain this element are widely used for nitriding. The Nitralloys are generally medium carbon steels containing also chromium and molybdenum, the latter being particularly effective in preventing the embrittlement which can occur in steels heated in the nitriding range. Nitralloy N contains 3½% nickel. Nickel and aluminum together form a precipitation-hardening steel, and it is fortunate that the optimum temperature for this reaction is the same as that ordinarily used for ni-
increased hardness and strength in
triding. Thus, it is possible to obtain the core during nitriding although there is some loss in ductility. With the other steels in this group, the core properties are unchanged during nitriding.

A special high carbon Nitralloy has been developed for applications as forgings or castings. This steel is tempered at a high enough temperature to precipitate a great deal of the carbon as graphite. Further increase in hardness and strength can be obtained by a subsequent quenching and tempering treatment.

The maximum case hardness is obtainable with the Nitralloy steels, but for some applications, somewhat lower hardness is desirable and steels containing no aluminum are used. Among such steels are the medium carbon AISI-SAE standard steels such as 4130, 4140, 6120, 8630, 8640 and 9440.

All of the stainless steels can be case-hardened by nitriding, and a number of them are used for this purpose. The straight chromium



Nitrided accessory drive gear used in the Wright Turbo-Compound Engine.

Some Nitriding Steels

Designation	C	Mn	Si	Cr	Al	Mo	Ni	Others
	Nominal Composition, %							
Nitralloy 135	0.30/0.40	0.40/0.70	0.20/0.40	0.90/1.40	0.85/1.20	0.15/0.25	..	..
Nitralloy 135, Modified	0.38/0.45	0.40/0.70	0.20/0.40	1.40/1.80	0.85/1.20	0.30/0.45	..	..
Nitralloy N	0.20/0.27	0.40/0.70	0.20/0.40	1.00/1.50	0.85/1.20	0.20/0.30	3.25/3.75	..
Nitralloy EZ	0.30/0.40	0.50/1.10	0.20/0.40	1.00/1.50	0.85/1.20	0.15/0.25	..	0.15/0.25 selenium
Nitralloy GR	*1.25/1.50	0.40/0.60	1.25/1.50	0.20/0.40	1.00/1.50	0.20/0.30	..	..
Stainless Steel	.45	..	..	14	..	.30	14	2.5 tungsten

NOTES:
Among standard AISI steels which are nitrided are 4130, 4140, 6120, 8630, 8640, 9440 and stainless types 302, 410 and 416.
** Total carbon.*

steels are more readily nitrided than the nickel-chromium steels, although both are used. Nitriding is also used to put a thin hard case on tool steels for certain applications.

Factors Influencing the Process

Since the depth of case depends on the diffusion of nitrogen from the "white layer" into the region below, time and temperature have considerable effects. For example, nitriding at 975 F will produce a deeper case than nitriding at 940 F in the same time. However, the lower temperature will produce the harder case. The depth depends also on the composition of the steel. Highly alloyed steels are penetrated less readily by the nitrogen than those less highly alloyed. Thus, the cases developed in stainless steels are shallower than those developed in the Nitralloys.

The hardness of the case depends on a number of factors also. The outer "white layer" is more brittle than the underlying layer which contains the precipitated metallic nitrides and is usually removed by grinding or lapping. Care must be taken in these operations, for cracking can result from too drastic grinding. The lower the temperature, the harder the useful case. However, a compromise temperature is necessary to obtain an adequate case depth together with suitable hardness. Aluminum is the most effective of the alloying elements, and cases produced on steels containing this element will give case hardnesses of 1050 to 1150 DPN, excepting that containing 3½% nickel which will run a little lower, perhaps 950 to 1050 DPN. Steels containing no aluminum will have cases of lower hardness generally in the range 600 to 900 DPN.

The structure of the steel is an important factor in obtaining suitable cases. For most effective hardening the steel must be quenched and tempered to obtain a sorbitic structure. The tempering operation is usually performed at 1100 to 1300 F, thus reheating to the 925 to 1050 F range required for nitriding causes no softening of the core.

The presence of free ferrite is undesirable and may result in brittle cases. Annealed or normalized steels are not suitable for nitriding. Decarburization resulting from heat treatment will also result in uneven hardness and brittleness in the case, and the decarburized layer must be ground off before nitriding to obtain satisfactory results.

The surface condition of the steel also affects the process. Rough surfaces are most effective, while burnished ones do not give satisfactory cases. However, many highly polished surfaces are nitrided. A scaled surface has a tendency to flake and give non-uniform results, an effect which is obtained also with decarbu-

Typical Core Properties of Nitriding Steels (Homerberg)

Designation	Condition	Yld Point, Psi	Ten Str, Psi	Elong, % (2 in.)	Red. of Area, %	Brinell Hardness
Nitralloy 135	Oil-quenched from 1750 F, tempered at 1200 F	120,000	138,000	20	58	280
Nitralloy 135, Modified	Oil-quenched from 1700 F, tempered at 1200 F	141,000	159,000	18	56	320
Nitralloy N	Oil-quenched from 1700 F, tempered at 1200 F	115,000	132,000	22	59	277
Nitralloy N	Oil-quenched from 1700 F, tempered at 1200 F, nitrided*	180,000	190,000	15	43	415
Nitralloy EZ	Oil-quenched from 1700 F, tempered at 1200 F	..	125,000	17	45	255
Nitralloy GR	Oil-quenched from 1650 F, tempered at 1375 F 5 hrs	84,000	108,000	18	19	..

** Properties show effect of precipitation hardening during nitriding.*

rized surfaces since these have a tendency to blister and peel.

Although it is necessary only to degrease the lower alloy steels to make them suitable for nitriding, the stainless steels require special treatment, for the inherent oxide film interferes with nitriding. In order to prepare the surface of these steels for nitriding, they can be preheated in a completely cracked ammonia atmosphere at 800 to 850 F, pickled in a hot hydrochloric acid solution, or etched electrolytically or chemically. Following such treatment they must be placed into the nitriding container immediately to prevent the formation of a new protective oxide coating.

Properties

The nitriding operation is performed at a relatively low temperature and no quenching is required. Distortion is reduced to a minimum, a factor which permits the finishing of parts to close tolerances before nitriding. This is one of the advantages of nitriding over carburizing. Some complex parts, which cannot be case-hardened satisfactorily by carburizing, can be nitrided without difficulty.

Wear resistance is an outstanding characteristic of the nitrided case and is the factor influencing its selection in most applications. Some qualification must be made because nitrided steels are more suitable for applications involving sliding friction than those involving shock since the case has a tendency toward brittleness.

The hardness of the nitrided case is unaffected by heating to temperatures below the original nitriding temperature, and substantial hardness is retained up to at least 1150 F. This is in marked contrast with a carburized case which begins to lose its hardness at relatively low temperatures. The retention of hardness is credited with being one of the major factors contributing to the wear resistance of nitrided steels.

Fatigue resistance is also one of the valuable features of nitrided steels. Surface scratches and tool marks, so influential in reducing the fatigue strength of steel, appear to have no effect on nitrided steels. Even notches, providing, they were formed before nitriding or do not completely penetrate the case, do not reduce the fatigue strength. These favorable fatigue properties are credited to the fact that the nitrided layer is in compression, a condition very favorable for resistance to reversed stresses. Numerous tests have shown that fatigue failure in nitriding steels tested to destruction originates near the boundary between the case and core, since this is the region of highest tensile stress. As a result, designing for applications of nitriding steel is usually based on the fatigue strength of the core rather than that of the case.

Although it is sometimes indicated that nitriding results in improved corrosion resistance, this is true only if the white layer is not removed. The corrosion resistance of the stainless steels, on the other hand, is reduced considerably by nitriding. and this factor must be considered when nitrided stainless steels are employed in corrosive environments.

Fatigue Strength of Nitralloy 135, Modified (Bittel)

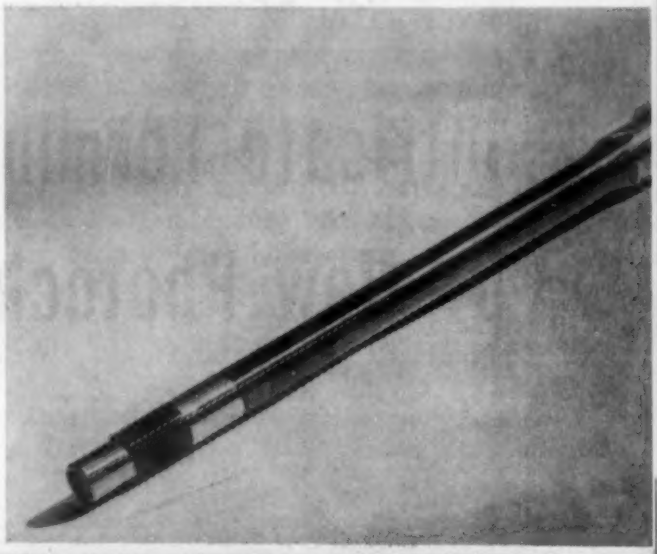
Condition	Fatigue Strength, Psi
Un-nitrided without notch	45,000
Nitrided without notch	90,000
Un-nitrided with half-circle notch	25,000
Nitrided with half-circle notch	87,000
Un-nitrided with "V" notch	24,000
Nitrided with "V" notch	80,000

NOTES:
Nitrided 40 hr at 975 F.
Rayflex vibrating fatigue-testing apparatus.

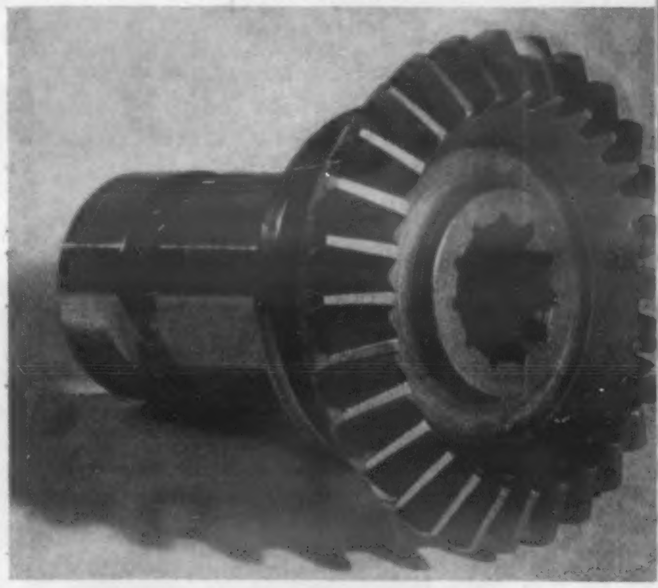
Applications

Most applications of the nitrided steels are based on their excellent resistance to wear, particularly toward sliding friction. Thus, they are used in cylinder barrels and liners for aircraft engines, bushings, shafts, piston pins, spindles and thread guides. Other applications require, in addition, freedom from distortion. These include cams and cam shafts, gears, rubber and paper-mill rolls, and boring bars.

A 14 chromium, 14 nickel, 2.5% tungsten stainless steel is widely used for airplane valves, the stem being nitrided for increasing wear resistance. High-speed tools are nitrided, usually in a cyanide bath, to obtain a light hard case, which increases the life greatly.



Main starter and accessory drive shaft for the Turbo-Compound engine nitrided by Wright Aeronautical to increase the wear resistance of the part.



Oil pump drive gear nitrided by Wright Aeronautical. Because distortion is reduced to a minimum, parts can be finished to close tolerances before nitriding.

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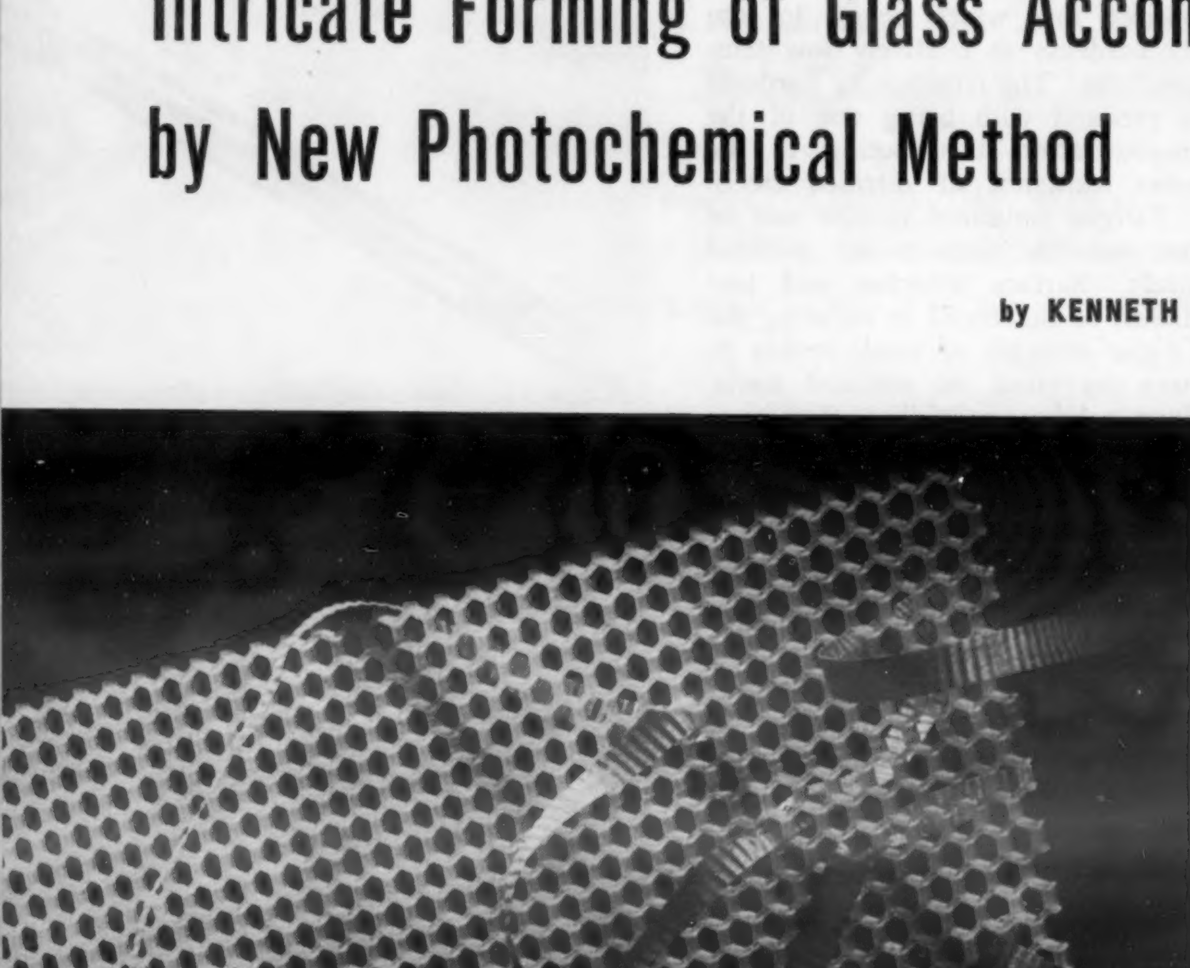
Intricate Forming of Glass Accomplished by New Photochemical Method

by KENNETH ROSE, Western Editor, Materials & Methods



The new photochemical method permits patterns to be etched to any depth, and holes to be cut through the thickness of the glass.

This "chemical machining" method used on special photosensitive glass replaces machining operations such as drilling, cutting, engraving and sand blasting, and produces patterns hitherto considered impossible in glass.

● GLASS IS A material with limited formability. Therefore, the recently announced photochemical forming method for glass should be of great interest to industry. It takes advantage of the transparency of glass to produce a pattern in the material, either on the surface or through the thickness of the piece, and then, by means of a differential chemical etching procedure, dissolves away the part of the glass modified by light to free the form desired. The process bears some resemblance to the chemical etching of metals, a method having very few applications in industry because it is so time-consuming; however, the combination of photosensitizing with the chemical treatment is unique in its application to glass.

The process was developed by Corning Glass Works, and is an outgrowth of the production of the photosensitive glass that was announced by the company in 1947. At that time there was produced a type of glass that underwent modification when exposed to strong ultraviolet light, so that it became milky after a subsequent heat treatment. This was used to produce designs in glass by using masks when exposing to the ultraviolet light, or to produce photographic scenes or pictures by irradiating through a photographic negative. As the image is integral with the glass, and therefore is not subject to removal by surface scratching nor to accumulation of dirt in recessed figurations, it found application in industry for the marking of dials and indicators of glass, in the production of diffusers for light, etc. The present glass used for photochemical forming is a special photosensitive composition, different from that used for the production of images in the glass, but processed similarly.

Steps in Process

The first requirement in the photochemical forming of glass is to produce a template or mask in which the open areas will correspond to the portion of the glass to be removed. If the piece to be produced is an elaborately designed shape of relatively thin cross-section, an opaque template can be used to mask that shape so that all the remaining portion of the glass can be sensitized and subsequently dissolved away. If a pattern is to be etched into the surface of the glass, a photo-

graphic negative can be used. A template can also be used to produce an etched contoured pattern in the surface of the glass by controlling the length and intensity of the exposure to light in the processing of the glass.

Actual processing begins with exposure of the glass, with the mask or template covering it, to ultraviolet light. The exposure time and the intensity of the light can be varied to give any desired depth of sensitizing in the glass. When a photographic negative is used for masking, the depth of tone of the negative will affect the irradiating time also. The glass is not visibly affected by the exposure, but a latent image is begun through the modification of the chemical composition of the glass by the ultraviolet light.

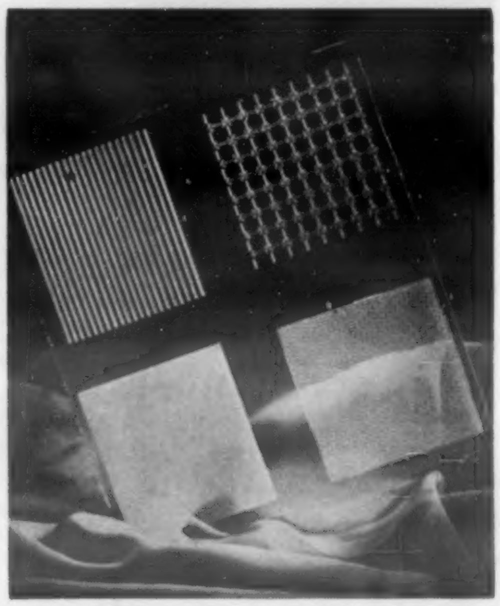
The next step consists of heating the irradiated glass in an oven at about 1200 F for a period of about 1 to 2 hr. The heat treatment brings out the latent image as a milky pattern in the glass corresponding exactly to the shape of the template or the photographic image used during the irradiating stage. The remainder of the glass remains clear. Another result of the heat treatment is that the composition of the glass is so modified that the clear portion is no longer photosensitive.

The milky portion of the glass is about 50 times as soluble in hydrofluoric acid as is the clear portion, and this is utilized to etch the design into the surface of the glass, or to dissolve away all the modified glass and free the form. The entire piece is immersed in a dilute solution of hydrofluoric acid, and the differential rate of attack causes the milky portion to be dissolved so much faster than the clear portion that the clear portion is for all practical purposes unaffected while the unwanted part of the glass is removed.

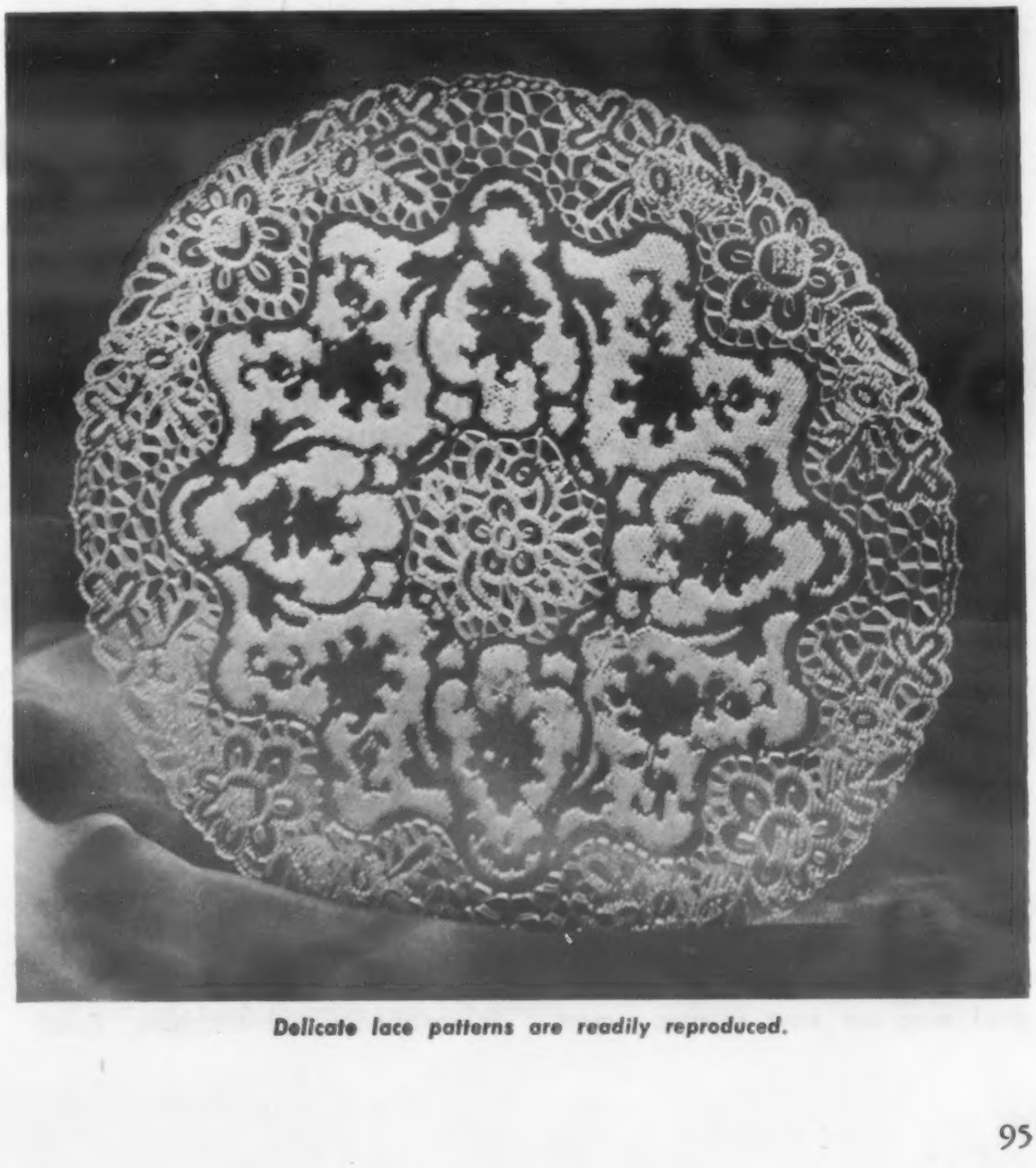
By this means, etched patterns can be given a depth and sharpness heretofore impossible. The patterns may be as intricate as can be prepared on the mask, and any number of pieces can be made, each a photographically precise duplicate. The method is well suited to mass production.

In artware, the new process holds out the possibility of preparing etched glass in patterns so intricate that their production by mechanical processes would be impractical or impossible. Delicate lace patterns, sculptured figures and contour shapes can be produced with a sharpness of detail never possible before on glass.

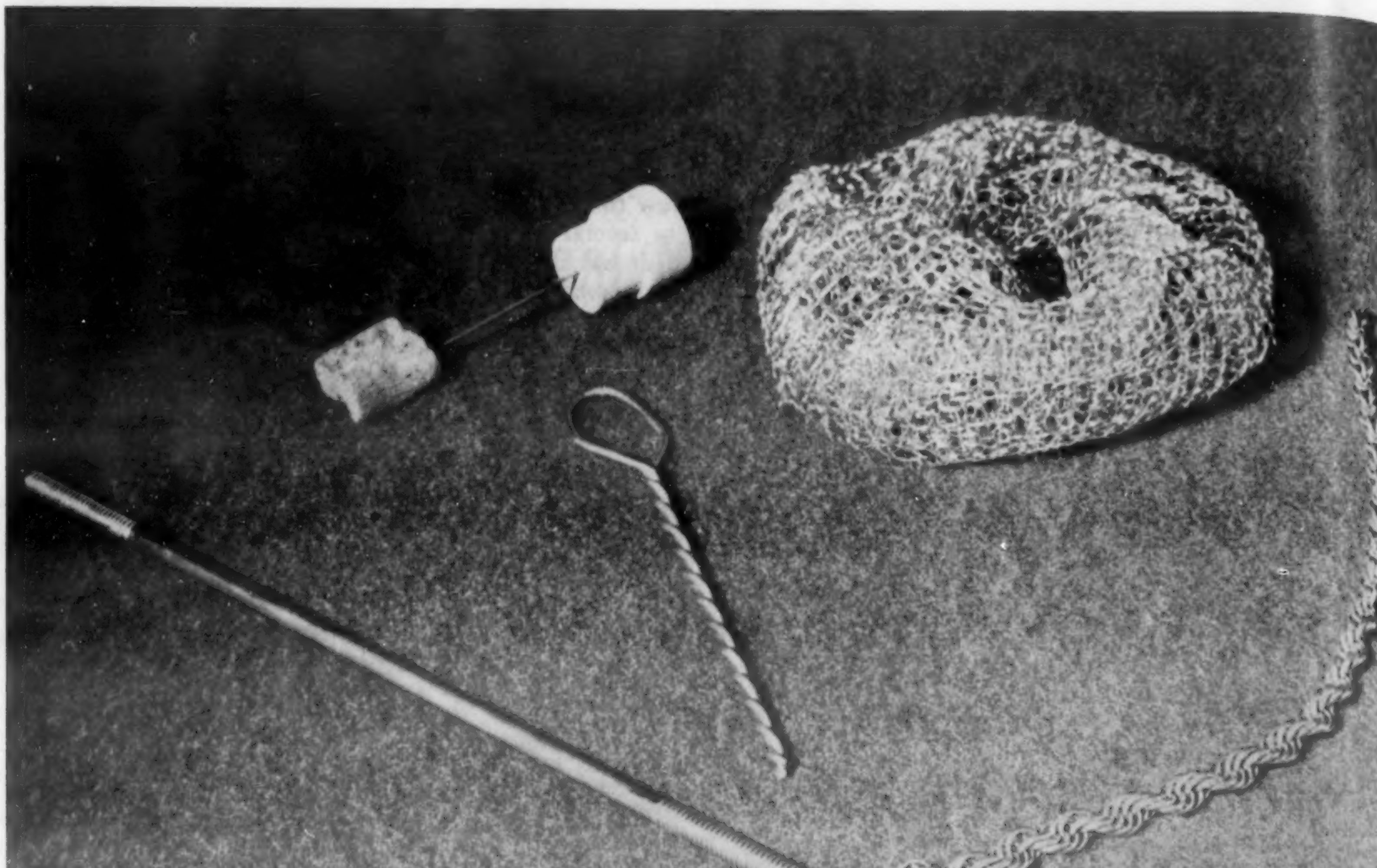
Industrially, the process makes possible the perforating of glass pieces with holes of any shape, of any size down to a few thousandths of an inch, and up to several thousands per square inch. It has already been used to manufacture plates for printed electronic circuits, the circuit being etched into the surface of the plate and filled with conductive metal, with holes being simultaneously formed for fastening to the chassis. Each pattern is identically etched, and because the plates can be made up as a large sheet and cut to individual plates after etching, production can be high.



Evidence of the scope of the new method are the samples with a variety of patterns, shown here.



Delicate lace patterns are readily reproduced.



A few typical products made from pre-plated drawn wire: lift rod with rolled threads, jewelry, pot cleaner, and shoe shine dabber.

Pre-Plated Drawn Steel Wire Saves Scarce Metals

Steel wire plated with either copper, brass or nickel and then drawn to size is finding many uses in both industrial and consumer fields because of its ability to be formed without flaking of the coating.

by HERBERT KENMORE, President, Kenmore Metals Corp.

● ELECTROPLATED WIRE that can be drawn, formed and otherwise processed without flaking of the coating is a relatively new development which is of particular significance during this period of metal shortages. By using a plating of copper or nickel on steel wire, instead of solid wire of these scarce metals, savings of over 90% can be realized. Because of the current scarcities, copper, brass and nickel plated steel wire are now receiving most attention from industry. However, nickel on copper and silver on copper are also available for suitable applications.

The Process

Briefly, in the Kenmore process a heavy coating of the desired metal is first electroplated on steel core wire and then the plated wire is drawn down to size by conventional drawing methods. The plating operation is continuous and automatic. Excellent adhesion is obtained by a special method of pre-treatment and intermittent coating of the steel surface before the desired metal covering is applied.

Low, medium or high carbon steel is used for the core wire, depending on the application. The initial diameter of the base wire is from 5/16 to 1/4 in. In the course of the drawing process the coated wire is annealed similarly to bare steel. The finish anneal is done at 1150 F and

an atmosphere furnace is used to give a bright finish.

By means of this process, wire is obtained that (1) has a uniform coating throughout the length of wire, (2) has a coating which is an integral part of the base wire, and (3) has the properties of cold worked steel plus the properties peculiar to the particular coating metal used. The mechanical properties of drawn plated wire are essentially the same as those of drawn unplated steel wire of the same composition.

One of the principal features of this wire is that it can be further shaped and worked by bending, flattening, swaging and even thread rolling operations without chipping or flaking of the coating. This is possible because of the excellent bond between the base wire and the plating resulting from drawing operations. The accompanying photomicrograph shows how the copper coating is worked into the surface of the base wire by the drawing operation.

Copper Plated Steel Wire

Drawn copper plated steel wire, called Copperon, is produced in sizes from 0.005 to 3/8 in. in dia. It can be obtained in rounds and also in flat wire with square or round edges. The thickness of the coating on the drawn wire is usually specified in percentage of total weight. Thus, although the actual coating thickness decreases as the wire is drawn to smaller sizes, the ratio of the coating thickness to the base wire remains constant. In general, coating thicknesses range from 0.5% to 12% by weight. Since the steel core wire weighs less than would a solid copper wire of the same diameter, Copperon wire provides about 5% more footage per pound than solid copper wire.

For uses involving ordinary electric currents the electrical conductivity of copper-steel drawn wire is about 25% that of copper. However, where high frequencies are involved, the currents travel on the conductor's surface, and, therefore, the conductivity of plated wire approaches that of solid copper. Thus, copper-coated steel wire is ideally suited for high frequency conductors. For example, the high frequency currents used in radar and television travel on the surface of the wire and not through the core; therefore, coaxial cable with a steel core and outer layer of copper is almost equivalent to 100% copper wire.

Copper plated wire can be welded by conventional resistance welding methods. However, careful control of timing factors must be observed so that plating will not discolor. The fine wire sizes (20 AWG and smaller) can be successfully soldered.

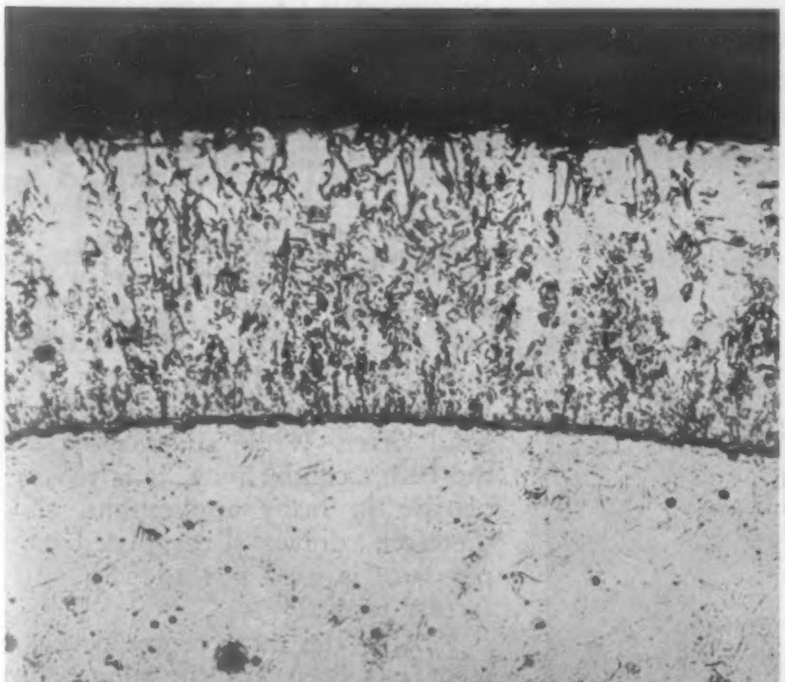
Copper plated steel wire has many present and potential uses in industry and particularly in electrical, electronic and communications applications. Some of the specific places where it has already been used are for power transmission and railway signal lines, television antennas and transmission lines, coaxial cables, heavy duty appliance cords, incandescent lamp leads, pigtails for capacitors and resistors, lightning rods, radio frequency coils, internal telephone wiring, plumbing products such as float racks and lift rods, and pot cleaners. Brass and bronze plated wire has been finding considerable use for ornaments, jewelry and curtain rods.

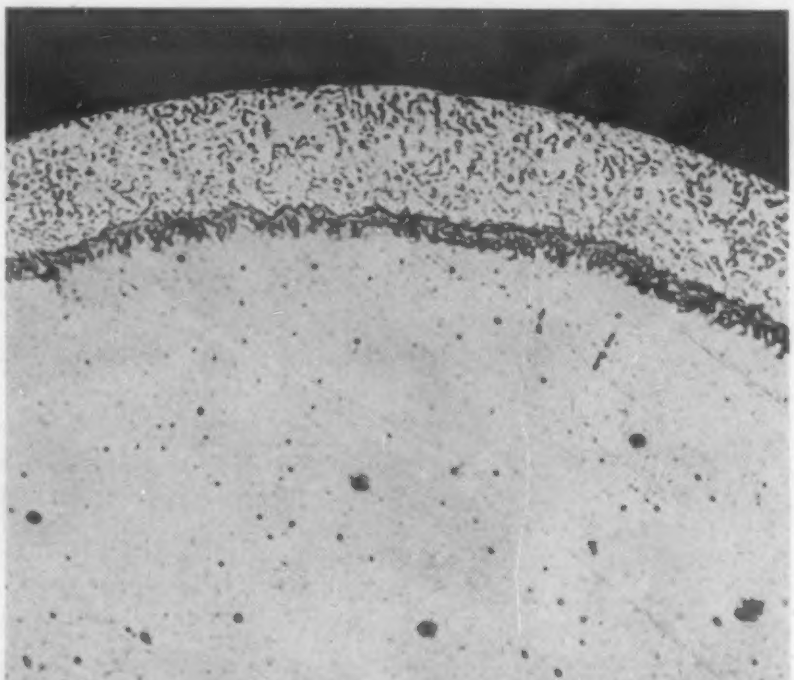
As pointed out earlier, one of the most important advantages of Copperon wire is that by using it in place of solid copper wire considerably less copper is needed. A typical example of this is the case of a producer of television antenna wire who, by switching from solid 30-gage copper to copper plated wire for a 300-ohm antenna, saved about 90 tons of copper on every 100-ton order of Copperon wire. In addition, he obtained the same performance characteristics and a longer lasting, higher strength wire.

Another example is the common lift and float rod used in water closets. This rod has traditionally been made of solid copper wire. Now, however, copper plated steel wire with a copper coating 5% by weight is being used successfully. The coating has proved sufficient to insure satisfactory corrosion resistance and the rod can be roll threaded without damage to the copper plate.

Nickel Plated Wire

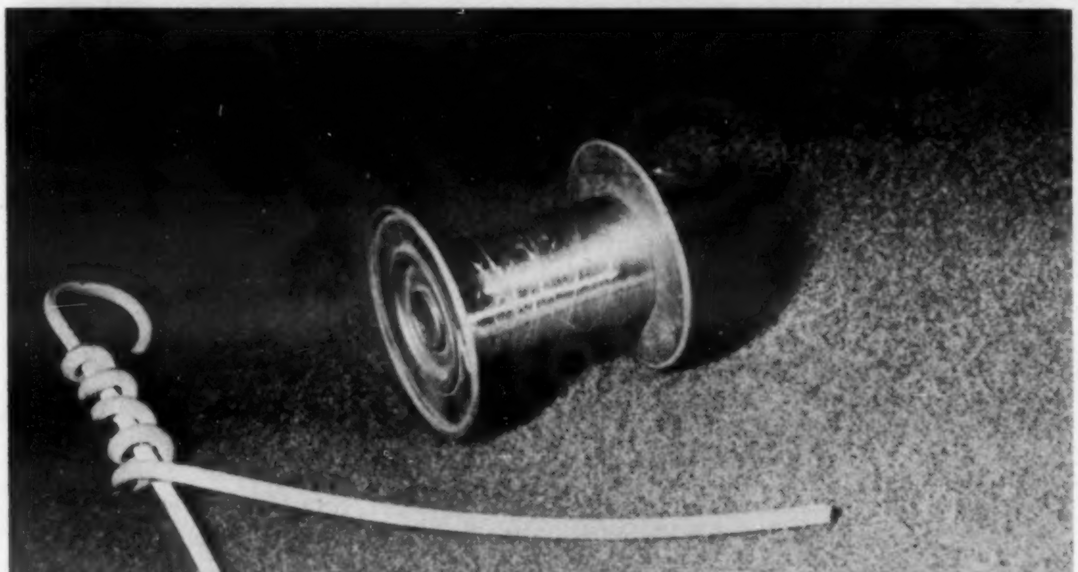
Nickel is plated directly on steel without an intermediary deposit of



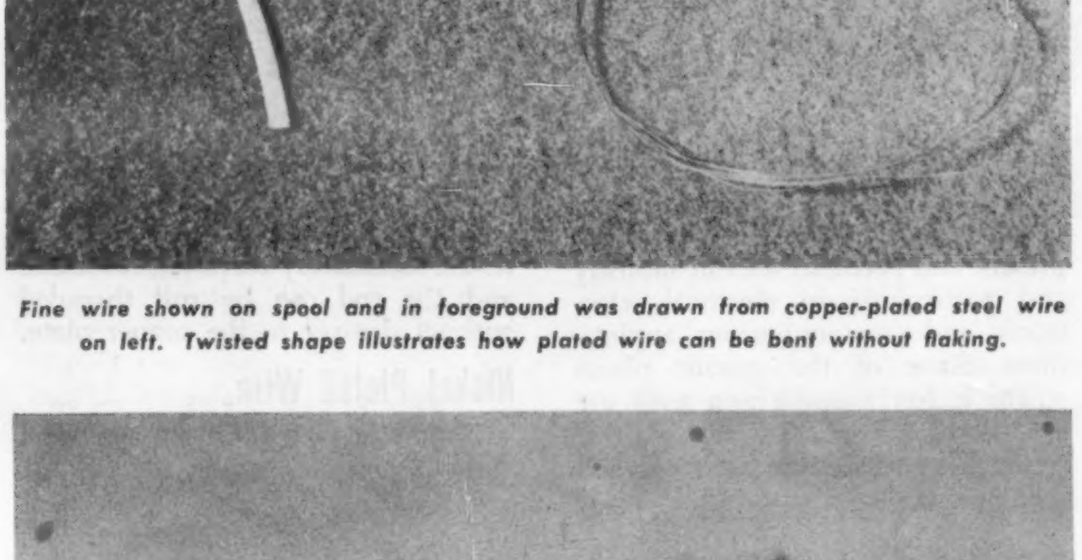


Photomicrograph at left shows cross section of steel wire as-plated with copper (200X). Photomicrograph at right shows copper-plated steel wire after being drawn down to size (500X).

copper. The wire is available in the same section shapes as copper coated wire. In general, sizes of round wire range from 50-gage to 5/16-in. dia. Flat wire has been produced up to a width of 3/8 in. The coating thickness can be as high as 0.002 or 0.003 in. The standard dry drawn nickel plated wire has a satin finish appearance. If desired, the wire can be so processed to give a super-bright finish.



Fine wire shown on spool and in foreground was drawn from copper-plated steel wire on left. Twisted shape illustrates how plated wire can be bent without flaking.



Copper-plated steel wire is finding wide use as wire filaments in tubes and lamps.

Nickel plated steel wire can be successfully spot and butt welded by controlling the timing factors so that the welding time is brief enough to prevent extensive diffusion from occurring. Thus, the nickel content at and adjacent to the welded joint remains high and provides corrosion resistance at least equal to the rest of the wire.

Nickel coated steel wire has been used for various spring products, and also for typewriter key levers. For closely coiled helical springs it has a particular advantage. By using pre-plated wire the entire spring is coated uniformly, whereas springs plated after forming receive the protective coating on only part of the diameter. In addition, the chance of hydrogen embrittlement is eliminated since the wire is plated in the patented stage and then drawn to spring temper. Other typical products made from nickel plated wire include lead wire, incandescent and fluorescent lamp wire, and automotive head light wire.

Nickel has also been plated on copper wire for ordinary and high power tube leads in the radio field, or for conductors where operating temperatures are above 300 F. Nickel, 5% by weight, is plated on 1/4-in. die scalped copper wire and drawn to 0.020, 0.016, 0.010 and 0.0064 in.

The preplated wire is highly advantageous in the appliance field as asbestos covered conductors for special heaters and high wattage lamps. It has a conductivity of as high as 95% of copper, whereas solid nickel, which is conventionally employed because of the high temperature, has only about 16% the conductivity of copper.

Preplated silver copper wire also has some promising uses in both the consumer and industrial field. A 1/4-in. copper wire can be coated with any desired thickness of silver. For jewelry, a 0.050 copper wire with a 10% plate of silver by weight is used. In the electrical and electronic industries, silver-plated wire is finding extensive use as a substitute for solid silver. While silver alone has the better conductivity, it is too expensive in many applications, and, therefore, drawn silver plated copper wire is used instead with satisfactory results.

Finally, the most recent development has been electroplating stainless steel wire by the same process, but the total production at present is reserved for the armed forces.

Precipitation Hardening Stainless Steels Show Advantages Over Standard Grades

by GORDON T. BEDFORD, Development Engineer, Armco Steel Corp.

17-7 PH and 17-4 PH steels can be readily cold or hot worked and welded, and with proper heat treatment, develop strengths equaling those of the carbon and low alloy steels at room temperature

● TO PROVIDE characteristics not previously available in stainless steel and to overcome the disadvantages of the standard stainless steels, the Armco precipitation-hardening stainless steels 17-7 PH and 17-4 PH were developed. These steels, which have been available for the past three years, can be severely cold or hot worked, or welded, and then heat treated at temperatures of 850 to 1400 F to develop strengths which, at ordinary temperatures, equal those of the carbon and low alloy steels. At temperatures up to 700 F, strengths are equal and in most cases superior to those of the best other structural material. Strength-weight ratios are high, and especially at elevated temperatures compare favorably with those of any other metal used in light-weight construction. The corrosion resistance of these steels, as determined in the laboratory, is generally superior to that of the hardenable stainless steels and is equal to 18:8 under some conditions.

Although cold work-hardened standard chromium-nickel stainless steels are available in light gages with high yield and ultimate strengths in tension, they do not have sufficient ductility to be suitable for severe forming operations. Of importance in highly stressed structures is the fact that their longitudinal compressive yield strengths are considerably lower than their tensile yield strengths.

The standard hardenable chromium stainless steels can be heat treated to develop high strength but not all are available in sheet and strip form, while their corrosion resistance is inadequate for some service conditions. These standard hardenable chromium alloys require high temperature heat treatment at 1750 to 1950 F to develop their full strength, and problems of scaling, decarburization, cracking and warping may be encountered.

The compositions and some of the physical properties of 17-7 PH and 17-4 PH are given in Table 1. Together, 17-7 PH and 17-4 PH embrace a wide range of sizes in plate, sheet, strip, bars, wire and forging billets. The 17-4 PH grade is also an excellent casting alloy. The designations for the conditions in which these grades are supplied, or which can be developed by heat treatment, are given in Table 2.

17-7 PH Plate, Sheet, Strip, Bars and Wire

A big gap that 17-7 PH is helping to fill is one that has existed in the manufacture of aircraft and guided missiles. Here, high strength structural sections and components have been produced from aluminum and magnesium alloys, and by severe forming and subsequent hardening of low alloy steels. However, in some applications conventional materials have not been sufficiently corrosion resistant, or not strong enough at the higher temperatures now prevailing in the structures surrounding aircraft power plants. Standard high tensile austenitic stainless steel has been used in some places for its high corrosion resistance and its strength under service conditions. However, these grades are lacking in some respects, as previously mentioned, and, therefore, are not ideal materials for complicated highly stressed structures.

The anti-shimmy damper is one of the applications of 17-7 PH and 17-4 PH in military aircraft.

Condition A—For such applications 17-7 PH plate, sheet and strip are supplied in Condition A with a 55,000 psi maximum yield strength, a hardness of Rockwell B 92, and an elongation of 40%. Having these properties, 17-7 PH can be drawn or severely formed. For example, an airplane manufacturer reported that their experience has shown that for most forming operations the same bend radii can be used as with annealed 18:8 stainless. After forming, 17-7 PH Condition A is heat treated to develop the properties indicated in Table 3. For other combinations of properties, different final heat treatments can be used.

Deep drawing or severe forming are entirely feasible with 17-7 PH

Condition A, but work-hardening during these operations is rapid and intermediate annealing may be necessary. This is done by heating at 1875 to 1925 F and air-cooling. Suggested holding time after the surface has reached temperature is 3 min for every tenth inch of thickness. Maximum softening and the best structure are not achieved if the steel temperature does not reach 1875 F. Surface scale produced during annealing can be removed by pickling practices effective on the standard stainless steels.

Condition T—After drawing or forming, a transformation heat treatment produces Condition T. This treatment requires 1½ hr at 1400 F, followed by cooling at any desired speed to 60 F or below. Condition T has useful properties with yield strength between that of ¼ hard and ½ hard types 301 or 302 stainless. For some applications these properties will be adequate, and no further heat treatment is necessary. However, this is usually an intermediate condition that is followed by a second heat treatment to produce Condition TH or THD.

The transformation that results from the 1400 F treatment begins only when the steel temperature has fallen to 250 F, and is not completed until the temperature drops to 60 F. It is not required that cooling to 60 F or below be uninterrupted. In fact, when water-cooling to 60 F or below, it is preferable first to air-cool to room temperature. Later—at any convenient time—cooling to 60 F or below can be completed. This procedure will minimize distortion. Transformation is accompanied by a dimensional increase of about 0.004 in. per in.; allowance should be made for this in lay-out, and any holes should be made after the transformation treatment and before the final treatment at 950 or 1050 F.

If any distortion occurs as a result of annealing or the 1400 F transformation treatment, straightening or re-striking should be done at room temperature, and before the final hardening treatment.

The 1400 F treatment produces a scale that can be removed by standard procedures at this stage if a final hardening treatment is not to be applied, or if straightening or re-striking of formed parts is needed. One fabricator finds that a light blast with Alundum grit removes scale adequately. The blast is followed by passivation in nitric acid.

During the 1400 F transformation treatment a bright, scale-free surface can be maintained by heating and cooling in a protective atmosphere of dry hydrogen or dry cracked ammonia.

Bars which require cutting after the 1400 F treatment should not be hot sawed or abrasive wheel-cut because very shallow cracks may appear. Cold sawing should be used unless the cut surfaces are to be faced. This precaution is unnecessary on plates, sheets and strip.

Conditions TH and THD—To obtain the very high strengths of Conditions TH and THD, the 1400 F treatment, which produces Condition T, is followed by a final treatment at a lower temperature. For the best combination of strength, impact resistance and ductility, the recommended treatment is at 1050 F for 1½ hr, followed by cooling to room

Table 1 — Composition and Physical Properties

Grade	Composition	Condition*	Density, Lb/Cu In.	Coef of Ther Exp per °F 70-800 F	Ther Cond, Btu/Sq Ft/In./Hr/°F at 300 F	Elect Resist, Microhm-cm	Magnetic Permeability, Max
17-7 PH	0.07 C 17.00 Cr 7.00 Ni 1.10 Al	H CH	0.278 0.277	6.7×10^{-6} 6.6×10^{-6}	117 114	86.5 83.8	111 77
17-4 PH	0.04 C 16.50 Cr 3.50 Ni 3.50 Cu	H	0.282	6.5×10^{-6}	124	77	151

* *See Table 2.*

Table 2 — Forms, Conditions and Heat Treatment

Grade and Condition	Condition Is Supplied by Mill in	Condition May Be Developed by Fabricator-Heat Treatment on	How Condition Is Developed
17-7 PH Condition A	Sheets, strip, plates and bars	Sheets, strip, plates and bars	Annealed at 1875–1925 F; air-cooled.
17-7 PH Condition T	Bars	Sheets, strip, plates and bars	Transformed by 1400 F, 1½ hr, followed by cooling at desired rate to 60 F.
17-7 PH Condition TH	Bars	Sheets, strip, plates and bars	1400 F as above plus hardened by 950 F, ½ hr, followed by air-cooling to room temperature.
17-7 PH Condition THD		Sheets, strip, plates and bars	For improved ductility. 1400 F as above plus hardened by 1050 F, 1½ hr, followed by air-cooling to room temperature. Hardening temperatures other than 1050 F can be used.
17-7 PH Condition C	Sheets, strip and wire		Cold worked.
17-7 PH Condition CH	Wire	Sheets, strip and wire	Mill cold worked plus hardened by 900 F, ½ or 1 hr; air-cooled to room temperature.
17-4 PH Condition A	Bars and wire	Bars and wire	Solution-treated at 1875 to 1925 F; air-cooled or oil-quenched.
17-4 PH Condition H	Bars and wire	Bars and wire	Solution-treated plus hardened by 850 to 900 F, 1 hr air-cooled.
17-4 PH Condition HD	Bars and wire	Bars and wire	For improved ductility. Solution-treated plus hardened by 950 to 1150 F, 1 hr; air-cooled.

temperature at any desired speed. Higher strength, with some sacrifice of ductility and toughness, is obtained by hardening at 950 F for ½ hr.

17-7 PH has excellent mechanical properties at elevated temperatures up to around 800 F. These properties exceed those of the standard stainless steels, low alloy steels, titanium alloys, aluminum alloys and magnesium alloys.

As with all other heat hardenable steels, strength is increased and ductility is lowered at sub-zero temperatures.

This material exhibits a shear strength about 70% of the ultimate tensile strength when sheared across the rolling direction, and about 65% of the tensile strength when sheared along the rolling direction.

Table 3 — Mechanical Properties

Grade	Condition*	Form	Ten Str, Psi	Yld Str, 0.2%, Psi	Elong, % in 2 In.	Red of Area, %	Rockwell Hardness	Izod Impact, Ft-Lb	End Str, Psi X10⁷ cycles
17-7 PH	A	Sheet or strip	130,000	40,000	30	..	B-85	..	..
	T	Sheet or strip	145,000	100,000	9	..	C-31	..	..
	TH	Sheet or strip	215,000	200,000	9	..	C-45	..	..
	THD	Sheet or strip	205,000	195,000	9	..	C-44	..	..
	CH	0.030-in. dia wire	325,000	320,000	..	..	..	..	..
		0.440-in. dia wire	255,000	250,000	..	..	..	..	..
		0.045-in. strip	250,000	240,000	..	..	C-49	..	..
17-4 PH	A	Bars	150,000	110,000	10.5	45	C-33	..	..
	H	Bars	195,000	182,000	10.5	45	C-43	15	90,000
	HD**	Bars	170,000	160,000	16	54	C-37	28	87,000
	HD***	Bars	155,000	148,000	15	57	C-35	36	82,000

NOTES:
** See Table 2.*
*** 1000 F, 1 hr, air-cooled.*
**** 1100 F, 1 hr, air-cooled.*
17-7 PH—Modulus of Elasticity; tension, 29,000,000 psi; torsion, 11,000,000 psi; elastic limit in torsion is about 55% of tensile strength.
17-4 PH—Modulus of Elasticity; tension, 28,500,000 psi; torsion, 10,500,000 psi.

Welding 17-7 PH

17-7 PH Condition A is easily welded by the metal-arc, inert-gas-shielded arc, and the various resistance welding processes. Welding procedures are like those for stainless Types 302 and 304. In contrast to the hardenable chromium standard steels, no pre-heating or post-annealing are necessary. Welding heat does not cause hardening in the heat-affected zones of the parent metal.

In ordinary metal-arc welding of 17-7 PH, coated electrodes of 17-4 PH should be used. Electrodes of 17-7 PH are not made because they would tend to lose some of their aluminum content by oxidation; therefore, the weld metal would lose part of its hardening capacity. The dilution of the 17-4 PH electrode with the melted 17-7 PH base metal

Table 4 — Elevated Temperature Mechanical Properties

Grade	Condition*	Temp, F	Short-Time Tensile Properties: Ten Str, Psi	Yld Str, 0.2%, Psi	Elong, % in 2 In.	Stress-Rupture Properties: Stress, Psi Causing Rupture in: 100 Hr	1000 Hr	Elong at Fracture, % in 2 In.: 100 Hr	1000 Hr	Creep Properties: Stress, Psi to Produce Creep Rate of: 0.1% in 1000 Hr	0.01% in 1000 Hr
17-7 PH	TH	70	206,500	184,500	9	..	..	..	..	..	..
		300	194,000	174,000	8	..	..	..	..	..	..
		400	189,000	167,000	6	..	..	..	..	..	..
		500	180,000	153,000	6	..	..	..	..	..	..
		600	171,000	141,500	6	162,000	161,000	9	7	145,000	130,000
		700	..	..	..	141,000	138,000	4	3	135,000	105,000
		800	153,000	116,500	8	124,000	100,000	6	5	50,000	..
		900	136,000	102,500	12	73,000	57,000	15	21	..	..
		1000	108,500	67,500	12	..	..	..	..	..	..
17-7 PH	CH	70	261,800	245,800	5	..	..	..	..	..	..
		300	248,000	233,500	4	..	..	..	..	..	..
		400	238,500	222,500	3	..	..	..	..	..	..
		500	228,000	214,000	3	..	..	..	..	..	..
		600	222,000	203,500	3	220,000	216,000	10	8	205,000	200,000
		700	..	..	..	194,000	180,000	11	9	150,000	125,000
		800	207,000	176,200	5	135,000	73,000	20	9	..	..
		900	182,400	143,500	6	53,000	36,000	14	12	..	..
17-4 PH	H	70	196,000	182,500	15	..	..	..	..	..	..
		500	170,000	150,000	10	..	..	..	..	..	..
		600	..	..	..	154,000	148,000	2.5	2	141,000	105,000
		700	158,000	138,000	10	134,000	130,000	2	2	120,000	80,000
		800	157,500	137,500	10	130,000	99,000	4	4	50,000	..
		900	140,000	110,000	10	81,000	48,000	4	17	..	..
		1000	99,000	74,500	15	..	..	..	..	..	..
		1200	58,000	43,000	15	..	..	..	..	..	..

** See Table 2.*

in arc-welding normally produces a weld deposit which can be hardened by the treatment regularly applied to 17-7 PH material. The corrosion resistance of 17-4 PH is equal to that of 17-7 PH. Strength of joints made with electrodes of 17-4 PH is better than 90% of that of the hardened parent metal when the assembly is hardened by the regular 17-7 PH treatment at 1400 F plus 950 F after welding.

For inert-gas-shielded arc welding filler rods or electrode wire of 17-7 PH analysis are quite satisfactory, because the weld metal is adequately protected against loss of aluminum. When the assembly is given the double heat treatment after welding, its strength is equal to that of the hardened parent metal.

All the resistance welding processes regularly used on stainless steels can be carried out satisfactorily on 17-7 PH Condition A. As with the standard stainless steels, it is important for weld soundness that electrode pressure be high in spot and roller seam welding. For the highest combination of weld strength and ductility in spot welds, the material should be given the 1400 F treatment before welding, then welded, and finally treated at 950 or 1050 F. Results are almost as good if both treatments are applied before welding, with none after. Joint strength is much lower when both heat treatments are applied after welding. This is explained by the fact that the weld nugget is subjected to high concentrated stresses because of the notch effect created at the junction of the joined pieces and the nugget. The ability of a weld nugget to withstand such stresses is a measure of weld metal ductility rather than of tensile strength. If the weld nugget in a 17-7 PH spot weld is hardened by a double treatment after welding, it becomes less ductile and so is less able to withstand the high concentrated stresses. This same principle applies in welding 17-7 PH to one of the standard stainless grades.

Typical tensile strength of unwelded 17-7 PH Condition TH is 215,000 psi and its shear strength is around 125,000 psi. In the same material a single spot weld that has been prepared properly for maximum strength has a shear strength around 65,000 psi. A wide gap between the strength of the base metal and that of a spot weld joining pieces of the same material is characteristic of all steels, for the reason discussed above.

The electrode found best suited for spot welding 17-7 PH is one with a domed tip, the radius of the dome being about 3 in.

Cross-wire spot welds on 17-7 PH wire are similar to spot welds on sheet, in the effect of welding and heat treating sequence on joint strength. Such welds are considerably stronger than similar ones in hard drawn 18:8 wire.

17-7 PH Spring Temper Wire and Strip

Another important need 17-7 PH is meeting is that for a stainless steel spring temper material having an elastic limit higher than that of 18:8 stainless and equal to the high carbon and alloy spring steels. The strength of 17-7 PH spring wire or strip is higher than that of the nickel-copper, nickel-aluminum and copper-beryllium alloy spring materials at ordinary and elevated temperatures. 17-7 PH Condition CH is the spring temper form of this grade, and in this condition it has the typical mechanical properties shown in Table 3. These are the properties available after forming the material received from the mill and then heat treating at 900 F for 1 hr and air-cooling.

Another important advantage of 17-7 PH over standard 18:8 stainless is dimensional stability when formed into springs. It has been observed that the dimensions of 17-7 PH springs are unaffected by the hardening treatment, and the ends and hooks on helical springs do not change position. When 18:8 springs are given the usual stress relief treatment, dimensional changes may occur which alter the load-deflection characteristics.

With 17-7 PH wire there is no hydrogen embrittlement problem in producing springs such as may occur on springs of carbon steel, low alloy steel or hardenable standard stainless grades when they are pickled after hardening or are cadmium plated for corrosion resistance.

17-7 PH Condition CH strip has very high endurance strength. A spring manufacturer found that it would withstand a higher stress than high carbon spring steel up to one million cycles of stress reversal. Between one and ten million cycles, 17-7 PH was equal to carbon spring steel. A manufacturer of motor springs reported that torque delivered by 17-7 PH springs was higher than usually expected from clock spring steel.

The excellent mechanical properties of 17-7 PH Condition CH at temperatures up to 800 F are illustrated in Table 4. For purposes of design, the short-time tensile properties will provide adequate information for service up to 600 F. 17-7 PH springs show considerably lower loss of load at elevated temperatures than do high carbon steels, alloy steels and 18:8 stainless steel springs.

The only heat treatment to be done on 17-7 PH spring wire or strip by the spring manufacturer is the 900 F 1-hr hardening operation, which is carried out after the coiling of springs or forming. Wire over 0.100-in. dia is usually supplied with a lead coating for spring-winding. This must be removed before the hardening treatment. It is done by immersion in 10 to 20% nitric acid at room temperature. Wire under 0.100-in. dia comes with a nonmetallic lubricating coating. This can be left on if wanted, or can be removed by nitric acid.

After heat treatment the springs can be cooled at any desired speed to room temperature. The hardening

Table 5 — Low Temperature Mechanical Properties

Grade	Condition*	Temp, F	Ten Str, Psi	Yld Str, 0.2%, Psi	Elong, % in 2 In.	Red of Area, %	Charpy V Notch Impact Str, Ft-Lb
17-7 PH	THD	80	196,000	181,000	9.5	..	5, 5
		32	195,000	174,000	6	..	5, 6
		−40	212,000	194,000	5.5	..	2, 4
		−80	219,000	204,000	2	..	3, 3
		−320	253,000	324,000	1	..	3, 4
17-4 PH	H	80	198,000	177,000	10	52	19
		32	203,000	180,000	16	53	19
		−40	209,000	186,000	17	53	8
		−80	218,000	194,000	17	52	8
		−320	263,000	243,000	7	10	4

* *See Table 2.*

Table 6 — Effect of Heat Treating and Welding Sequence on Mechanical Properties of Metal-Arc Welds and Inert-Gas-Shielded Arc Welds in 17-7 PH Conditions A, T and TH

	1. 1400 F 2. 950 F (Unwelded)		1. Welded 2. 1400 F 3. 950 F		1. 1400 F 2. Welded 3. 950 F		1. 1400 F 2. 950 F 3. Welded	
	Metal-Arc	Inert-Arc	Metal-Arc	Inert-Arc	Metal-Arc	Inert-Arc	Metal-Arc	Inert-Arc
Rockwell Hardness								
Parent Metal	C45	C45	C44	C45	C44	C45	C44	C45
Weld Metal	..	..	C40	C45	B96	B90	B90	B85
Tensile Strength, Psi	200,000	200,000	187,800	200,000	145,200	135,000	142,500	127,000
Joint Efficiency Based on Tensile Strength, %	..	..	94	100	72	67	71	63
Elongation, % in 2 In.	12.0	12.0	5.4	9.0	6.2	14.0	6.2	12.0
Location of Fracture	..	..	Weld metal	Base metal	Weld metal	Weld metal	Weld metal	Weld metal

NOTE: Double-bevel butt joints in 1/4-in. plate, metal-arc welded with 5/32-in. coated electrodes.
Square-butt joints in 1/4-in. plate, prepared by argon-shielded tungsten-arc welding, using one pass on each side and adding no filler metal.

Table 7 — Effect of Heat Treating and Welding Sequence on Mechanical Properties of Metal-Arc and Inert-Gas-Shielded Arc Welded 17-4 PH

	1. Solution-Treated 2. 900 F (Unwelded)	1. Solution-Treated 2. 900 F 3. Welded	1. Solution-Treated 2. Welded 3. 900 F	1. Solution-Treated 2. 900 F 3. Welded 4. 900 F	1. Solution-Treated 2. Welded 3. Solution-Treated 4. 900 F
Rockwell Hardness					
Parent Metal	C43	C43	C43	C43	C43
Weld Metal	..	C30	C44	C45	C43
Ultimate Tensile Strength, Psi	200,000	150,000	185,000	185,000	195,000
Elongation, % in 2 In.	10.0	5.0	6.0	7.2	5.5
Fracture Location	..	Weld	Weld	Weld or base metal	Weld
Joint Efficiency Based on Tensile Strength, %	..	75	92	92	98

NOTES: (a) Double-bevel butt-joints in 1/4-in. plate, metal-arc welded with 5/32-in. flux-coated electrodes of Armco 17-4 PH.
(b) Square-butt joints in 1/4-in. plate, argon-shielded tungsten-arc welded using one pass on each side and adding no filler metal.

treatment also serves to relieve normal cold-forming stresses in the wire, and a separate stress relief treatment is not applied. When the heat treatment is done in air, a heat tinting or coloring occurs. This has no dimensional importance and it can be removed quickly with a 10 nitric-2% hydrofluoric acid solution at 110 to 140 F, or by electropolishing.

17-7 PH Conditions C or CH are readily welded by the inert-gas-shielded arc method. However, the strength and hardness of fully hardened material cannot be obtained in and around the weld because after welding, these areas behave like annealed material and do not respond to the single 900 F hardening treatment. If the steel is given the 900 F treatment and then welded, softening occurs around the weld. For example, a weld in 0.050-in. thick sheet material will have a tensile strength of about 155,000 psi, which is not affected by heat treatment either before or after welding. If 17-7 PH Conditions C or CH are to be fusion welded, it must be done at a point in the assembly where a strength lower than that of the fully hardened metal can be tolerated.

17-4 PH Bars

High strength and hardness are available in bar material of the standard heat hardenable stainless grades of the 400 series such as Types 410, 414, 416 and 431. However, the high hardening temperatures required may present problems of scaling, decarburization, distortion, and even cracking. These problems do not arise when 17-4 PH bars are used since the hardening is done at 850 to 1150 F followed by air-cooling, instead of at 1750 to 1950 F. This treatment produces hardnesses up to Rockwell C 45. Yield strength is considerably higher than for the standard chromium stainless grades, and is similar to that for hardened low alloy steels. As supplied in the solution-treated condition, 17-4 PH Condition A is readily machined, welded and forged. Mechanical properties are given in Table 4. When maximum strength

and hardness are desired, hardening is done by heating 1 hr at 850 to 900 F and air-cooling to room temperature. Substantially higher impact strengths can be obtained by hardening in the range 900 to 1150 F. With these treatments the yield strength will still be above or equal to that of fully hardened and stress relieved stainless Types 403, 410, 414, 416 and 431.

Hardening of 17-4 PH produces only a heat tint, or very light oxide film, easily removed by a few minutes pickling in a 10 nitric-2% hydrofluoric acid (by volume) bath at 110 to 140 F. Long exposure of machined or polished parts to the pickling solution should be avoided because of acid etching the surface. At the same time, this treatment removes such embedded foreign material as particles of tool steel from machining operations, and produces a chemically clean (passivated) surface with maximum corrosion resistance. The heat tint can also be removed by electropolishing.

The combination of high endurance strength with excellent corrosion resistance has been a factor in the selection of 17-4 PH for important defense applications. When tested at 700 F, 17-4 PH hardened at 1050 F has an endurance strength about 90% as high as at room temperature. For material fully hardened at 900 F, the elevated temperature endurance strength would probably be about 5000 psi higher than when hardened at 1050 F.

High endurance strength and high creep strength, with high strength-weight ratio and excellent corrosion resistance at moderately elevated temperatures make 17-4 PH or 17-7 PH ideal for such applications as compressor blading in jet engines and other gas turbines.

Good resistance to impact and high strength at below zero temperatures, coupled with high corrosion resistance, makes 17-4 PH suitable for such critical applications as aircraft landing gear parts, ordnance, and valves for cold-country oilfields.

Machining—One of the chief advantages of 17-4 PH is that it can be machined to final size in Condition A without allowing for scaling or distortion in the subsequent full hardening treatment, because of the low temperature of the latter. 17-4 PH, Condition A, is machinable at rates about the same as those used with Types 403 or 410 stainless heat treated to around Brinell 300. An excellent finish is obtained. In machining of airplane landing gear parts, etc., 17-4 PH has been found to have a real advantage over 18:8 in either the annealed or cold worked conditions.

Forging—17-4 PH can be hot forged readily. This alloy scales much less at forging temperatures than the hardenable standard stainless grades. Besides the metal saving, this means better surfaces on forgings, less damage to dies, and easier scale removal. Blanks should be heated uniformly to 2150 to 2200 F and held at temperature not less than 15 min before forging. If forgings are finished above 1800 F and rapidly air-cooled or oil-quenched, a solution treatment can be avoided. Water-quenching is not recommended. It may be desirable to transfer large or intricate forgings directly from the hammer to a furnace for solution treatment.

The valve stem illustrated is an excellent example of severe forging of 17-4 PH. The material is upset, then drop forged to form the four thin radial fins. At the other extreme, an ingot 30 in. in dia has been satisfactorily forged down to 16 in. in dia, and a 21- by 23-in. ingot has been reduced to 9 in. square without trouble. The 16-in. round has been sawed into blocks, upset into disks, punched, expanded, and rolled on a ring mill to rings about 43 in. O.D. by 40 in. I.D.

In cutting forging slugs from billets or bars, it is best to use a cold saw. Hot or abrasive cutting may produce very shallow cracks.

Solution Treatment—Forgings can be solution treated by holding at 1875 to 1925 F for 30 min, followed by air-cooling or oil-quenching. Air-cooling is recommended for sections over approximately 3 in. thick, or of intricate shape, to minimize the possibility of quench-cracking.

Scale Removal—Scale produced in forging and solution treatment can be removed in a two-stage operation. Parts are treated first in a 15 to 20% by weight sulfuric acid bath at 150 to 190 F for 10 to 45 min, then rinsed. Next, a solution containing 6 to 15% nitric acid and ½ to 1½ hydrofluoric acid by volume is used to finish scale removal and whiten the surface.

The sodium hydride method can be used instead of sulfuric acid. However, if a temperature of 750 F and time of 15 min are exceeded, some hardening may occur.

Welding—17-4 PH is readily welded by any of the methods usually employed on chromium-nickel stainless steels and has all their good welding characteristics. At the same time, welded 17-4 PH is not subject to the intergranular corrosive attack that may occur in some environments as a result of welding 18:8 Types 302 and 304 stainless. Also, 17-4 PH is without the undesirable features of the conventional hardenable chromium grades; thus, preheating and annealing after welding are unnecessary.

For metal-arc welding, coated electrodes are used, which deposit weld metal of the same analysis as 17-4 PH. Welds can be hardened by the same simple 850 to 900 F treatment used for 17-4 PH base metal. When 17-4 Condition A is welded and then hardened, joint strength is about 92% of that of fully hardened base metal. However, if the joint is solution treated after welding, then hardened, this figure is raised to around 98%. Untreated welds made on previously hardened material have a joint efficiency of about 75%; but this can be increased to above 90% by rehardening after welding. Mechanical properties of welds made by the metal-arc and inert-gas-shielded arc methods are similar. When it is unnecessary to have precipitation-hardening weld metal in the joint, an electrode or filler rod of regular chromium-nickel analysis, such as Type 308, can be used to secure a more ductile weld.

High strength cross-wire spot welds can be produced in 17-4 PH. The highest joint strength is obtained when the wire is hardened before welding and the joint is not subsequently given a hardening treatment.

Resistance to Galling or Seizing—When lubricants cannot be used, a high surface finish will minimize chances of galling. Laboratory tests have indicated that when hardened 17-4 PH is in contact with solution treated 17-4 PH, this combination has much higher resistance to galling than does standard 18:8 stainless in contact with itself or with hardenable standard stainless steels. Galling resistance is lowered considerably when hardened 17-4 PH works against hardened 17-4 PH, and when solution-treated 17-4 PH is in contact with solution-treated 17-4 PH. A large difference of hardness is also desirable when 17-4 PH is used in sliding contact with some other steel.

Northrop Aircraft workers cast a phenolic resin mix into the mold for a jig master for main landing gear door of a Scorpion F-89.

New Casting Resin Used for Low Cost Forming Tools

by JOHN STARR

Long lasting, accurate jigs and dies are rapidly and easily produced with this phenolic resin that has low viscosity and does not readily retain air bubbles as it solidifies.

● DRILL AND ASSEMBLY jigs, stretch dies, form blocks and many similar production tools are now being made at an exceptionally low cost without a sacrifice of quality for the aircraft industry by means of an unusual phenolformaldehyde casting resin. This resin is produced as an A-stage phenolic liquid by Baker Oil Tools, Inc., Los Angeles. It is said to exceed the tooling properties of other phenolic casting resins because it has been plasticized for extremely low viscosity and will not readily retain air bubbles as it solidifies.

A catalyst or acid hardening agent is added to the resin for casting purposes, after which it can be poured into numerous types of inexpensive molds for solidification in a comparatively short period of time by low-temperature heating. Prop-

erties of the solidified casts are typified by data in an accompanying table.

Patterns for the tooling casts can be made in a conventional manner from wood, metal and plaster materials. Shrinkage allowances are variable to a certain extent, depending on casting conditions which can be briefly summarized as follows:

1. If no special fillers are incorporated in the casting resin, and if a normal curing temperature of 170 F will be used to solidify the tooling casting, shrinkage will be 0.006 in. per in.

2. If fillers such as asbestos are added to the casting resin (for purposes which will be discussed presently), or if a curing temperature of 140 F will be used to polymerize a tooling cast, shrinkage will be 0.003 in. per in.

3. Combinations of special fillers (such as asbestos and boric acid powders) and low curing temperatures, as noted above, can be used if necessary to reduce shrinkage to about 0.001 in. per in.

Incidentally, higher curing temperatures are preferred where shrinkage is not an important factor because they reduce the time required to solidify a tooling cast.

Molds for Casting Resin

Molds for casting the Baker resin may comprise numerous materials, and they have been fabricated both with and without special tooling patterns in general conformity with the following considerations:

1. *Cast plaster molds*—normally made where patterns are available; have the advantage of being most economical where the purpose of a mold is to duplicate less than a dozen casts.

2. *Wood molds*—generally made where the shape of a cast is relatively simple, since wood materials can be rapidly assembled as molds in such circumstances without special patterns.

3. *Metal molds*—can be cast or machine fabricated from numerous alloys; are desirable if numerous casts must be duplicated with maximum dimensional accuracy.

4. *Flexible molds*—comprising cast rubber latex or vinyl plastic elastomers; can be economically fabricated and used indefinetely if requisite tooling casts are not too large, or if extreme dimensional accuracy is nonessential.

Where open-faced molds were required, two important difficulties have been encountered. First, if the back surface was inclined to be rough due to the meniscus at the mold edges, the casting resin had an undesirable tendency to pile up at the point where it was poured. Secondly, relatively thin castings were inclined to be warped due to a concentration of shrinkage stresses in those portions of the materials which were exposed to the atmosphere in curing.

The first of these difficulties has been eliminated in some circumstances by machining a flat on each of the solidified plastic casts. The second difficulty is rarely encountered when the length of a casting is not more than three or four times its thickness. However, Northrop engineers feel that the best procedure is to avoid the possibility of discrepancies in either case by preparing a mold cover.

Each mold cover ordinarily comprises two wood or plywood parts. The first part is placed on a mold shortly before the mold is fully loaded, after which casting resin is poured into the partly-covered cavity until the latter is slightly over-loaded. Then the second part of the mold cover is placed over the mold cavity, so as to squeeze out the excess casting materials and to flatten the surfaces adjacent to the cover as the tooling cast is cured.

Closed molds with risers are used where casts of exceptional homogeneity are required, if the mold dimensions are such that they can be centrifuged. On-center centrifugal action is, of course, required to expel air bubbles via the risers.

Molds are cored for the primary purpose of conserving the casting resin, where such a procedure involves no sacrifice of tooling strength. For example, as shown in accompanying illustrations, molds for casting stretch dies are often cored so that the dies will have 4-in. wall sections.

When tools of the latter type must have large dimensions, plastic cross members are necessary to support each die on 12-in. centers. Such cross members are cast in the tool by means of a core with one side shaped approximately to the surface contour of the die. All edges or corners of the core are rounded to ½-in. radii to prevent stress concentrations in tooling casts, and the core is mounted on a backing section which can be firmly attached to a mold so that it will not float when a liquid is poured into the mold.

Cores comprise the same materials as molds, except where globular or oversized chambers must be produced in tooling casts. Special wax or paraffin cores are used in the latter circumstances, because they will melt and flow out a plastic cast when the latter solidifies.

Molds and cores made with porous materials such as wood and plaster

Typical Properties of Phenolic Tooling Resin

	Resin with No Filler	Resin with 25% Walnut Shell Flour	Resin with 8% Asbestos
Mold Shrinkage, In. per In.	0.006	0.006	0.0025
Specific Gravity	1.21	1.17	1.21
Specific Volume, Cu In. per Lb	22.8	23.7	22.8
Tensile Strength (½-by ½-In. Sample), Psi	7000	3600	3000
Modulus of Elasticity in Flexure Fiber Stress of 1000 Psi in Psi X 10^5	2.6	2.6	..
Compressive Strength, Psi			
Yield Point	9000	8100	6500
Ultimate	9600	8500	8000
Flexural Strength, Psi	9600	4000	..
Izod Impact Strength per In. of Notch (½-by ½-In. Notched Bar), Ft-Lb	0.18–0.36	0.18–0.36	0.22–0.30
Rockwell Hardness (L Scale, 60 Kg, ¼-In. Ball)	95	60	..
Thermal Expansion, In. X 10^{-5} per In. per °C	9.3	9.3	2.7
Resistance to Continuous Heat, F	160	160	160

compositions are seal-coated with lacquer, shellac or a similar medium prior to use. Then, before each cast is poured, the sealed cavity surfaces are coated with a parting agent—usually a wax emulsion or linseed oil. Nonporous metal or flexible molds require no seal coatings, but parting agents are often required to facilitate the removal of casts made therewith.

Fillers Used

Fillers such as asbestos powder, wood flour, etc., are incorporated in the casting resin to increase the bulk (and thus to reduce the cost) of the resin; also, to permit the casting of tools with special physical properties, such as better heat resistance. Then, with each ten parts of resin by weight, one part of catalyst is mixed. The catalyst is modified hydrochloric acid solution; and, like the filler, it is usually mixed with the casting resin by means of a mechanical agitator.

The resin is usually poured as soon as the catalyst is thoroughly dispersed therein because the catalyst will eventually cause the liquid plastic to thicken or solidify, regardless of whether the casting mix is heated.

Elevated temperatures are used to accelerate the action of the catalyst after a casting resin mix is poured into a mold by placing the loaded mold in a thermostatically controlled oven. Temperatures of the oven are varied as previously indicated, and the time required to cure a given tooling cast depends on the dimensions of a mold and its ability to conduct heat as well as the oven temperature in any given circumstance. However, if a maximum curing temperature of 170 F is used, small casts (weighing less than 10 lb) are ordinarily solidified in less than 3 hr while large castings (weighing as many as 2000 lb) will polymerize in 8 to 18 hr.

To eliminate the possibility of after-shrinkage or thermal distortion, the molds and casts are allowed to cool to room temperature before they are separated. Then, if necessary, details such as threaded holes and grooves are machined on the tooling casts—much the same as identical details would be machined on a hard grade of wood.

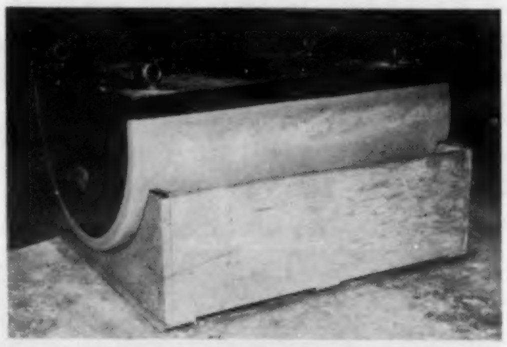
The tooling casts ordinarily have a light pink color, which is not objectionable for most tooling purposes. However, this has been varied in certain circumstances by adding pigments such as lampblack to uncured casting materials or by coating the polymerized casts with standard lacquers or enamels.

Where casts have been made in closed or covered molds without centrifugal action, plastic surfaces adjacent to the uppermost part of the mold or mold cover have sometimes been pitted because air bubbles in the cast resin could not escape. This was not objectionable in many circumstances, because the pits did not appreciably affect the overall properties of the tooling casts. However, such discrepancies have been satisfactorily eliminated by brush coating the surfaces with freshly-catalyzed resin so that the latter could be solidified and permanently bonded to the tooling casts with heat from infra-red lights.

In many circumstances, metal inserts have been cast in plastic tools; for instance, where the latter were to be used as drill jigs. This involved no difficulties where the inserts had no sharp edges (which would tend to crack or chip solidified plastic materials), or where the inserts were organically finished prior to casting operations so that there would be no corrosion or undesirable chemical reactions due to the use of acid catalysts.

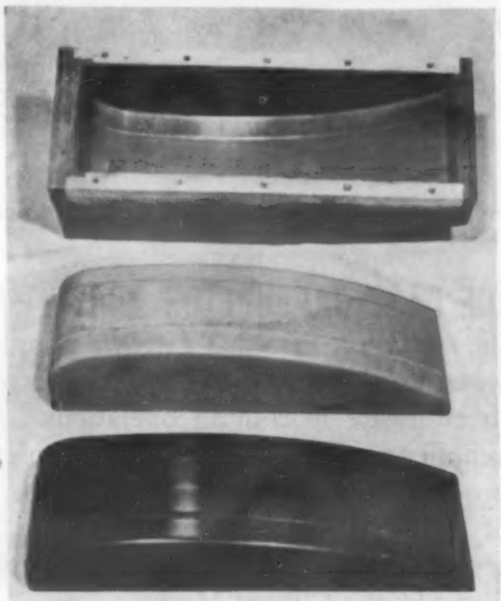
There is no practical limit to the life of a cast plastic tool if the margin of safety observed in designing the tool is such that it will not be exposed to the conditions that will cause the plastics to fail. For example, Douglas Aircraft Co. has reportedly used unfilled phenolic form blocks (with 9600 psi ultimate compressive strength) to fabricate more than 10,000 sheet metal stampings, each, where forming pressures did not exceed 7000 psi per press operation.

The low cost of cast plastic tools is primarily due to the speed, ease and accuracy with which such tools can be made. For instance, cost statistics from the Northrop Aircraft plant reveal that each pound of hardwood (worth about 50¢) requires an expenditure of at least $2.00 to convert the wood into the base for a drill and trim fixture, whereas a pound of phenolic casting resin (costing 75¢) can serve the same purpose at a total fabricational cost of less than $1.00.



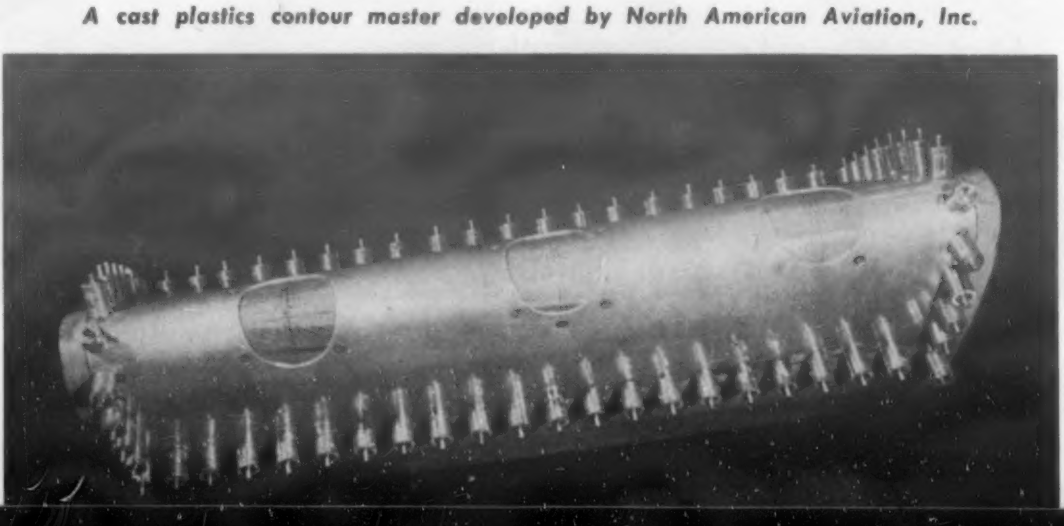
A finished plastics stretch die and handling cradle for a fuselage section.

Phenolic saw fixture used at Northrop in fairing skin. Fixture is rotatable so that each part can be trimmed on three sides.



A female pattern (top) and the male hydropress form blocks made with the new phenolic casting resin at Consolidated Vultee Aircraft Corp.

A cast plastics contour master developed by North American Aviation, Inc.

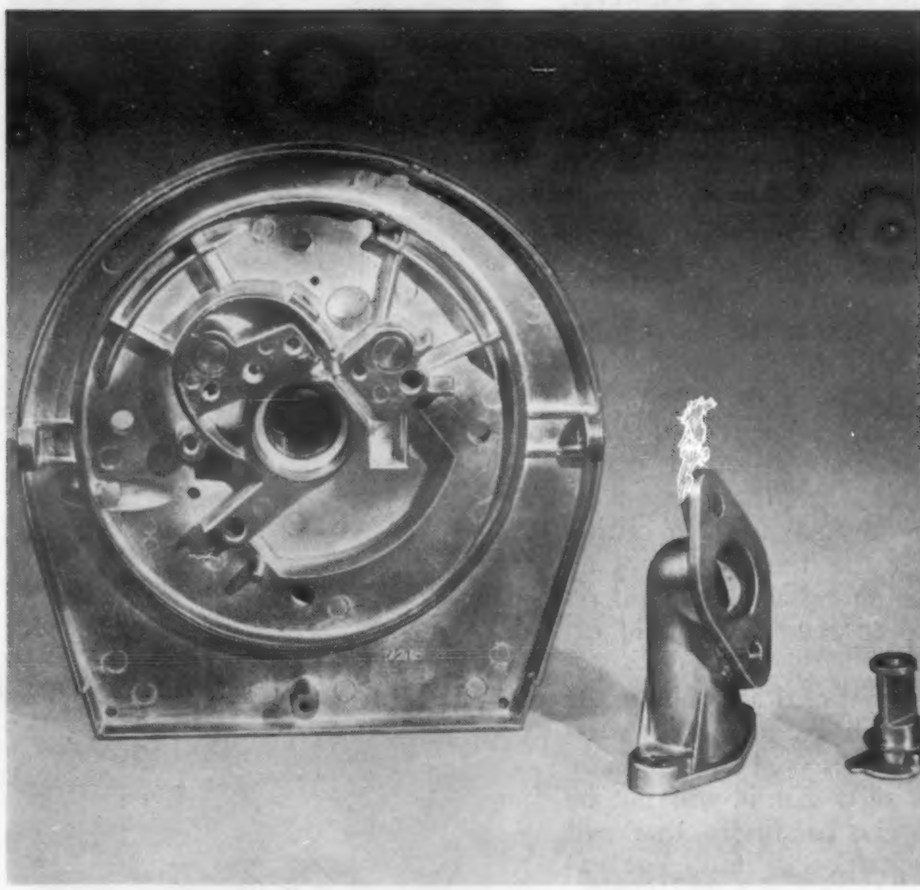


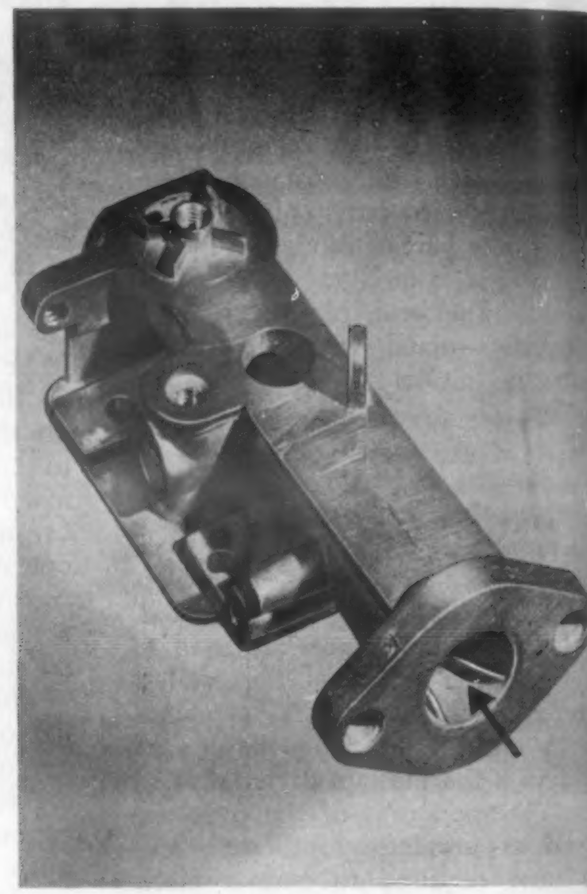
Materials at Work

Here is materials engineering in action . . .

New materials in their intended uses . . .

Older, basic materials in new applications . . .





DIE CAST CARBURETOR BODY It is one of the virtues of the die casting process that extreme complexity of shape can be achieved when desired—to make one part serve in place of two or more, or to eliminate machining operations. Although designers strive for simplicity, it is often true that complexity can be an asset if over-all production economies can be effected. Such is the case in the design of the zinc die cast carburetor body. The carburetor body is one of several zinc die castings used in assembling the various engines produced by the Clinton Machine Co.

Holes and recesses are cored in five directions in die casting the carburetor body, and one of the holes (see arrow) is obtained with a coarse helical thread on its inner walls. Such a thread, having several starts, probably could be produced commercially in no other way, unless cut by a very special broach costing much more than the rotating core used in the die casting operation.

All of the holes and recesses not parallel to the motion of the die are produced with movable cores, of course, to permit ejection of the carburetor casting from the die. Such cores add to die cost and slow the casting operation, but are completely justified by the over-all production economies achieved. To obtain all of the holes and recesses by any other method of production would require a built-up assembly of several parts, or would involve excessive machining.

GLASS-REINFORCED PLASTIC SEAT

Smith and Stone Ltd., of Toronto, Canada, is now manufacturing a glass reinforced plastic seat for the pilots and co-pilots of a new De Havilland airplane. The seats are designed to provide riding comfort and safety in the event of an accident. In tests, a lap belt load of 1440 lb, and a back pull through the shoulder harness of 900 lb, were applied simultaneously. The plastic seats can also be produced in one-half the time it took to fabricate aluminum. The edges are rolled to prevent snagging equipment in use. The seats are secured in the plane on all-magnesium castings that lock into the floor.

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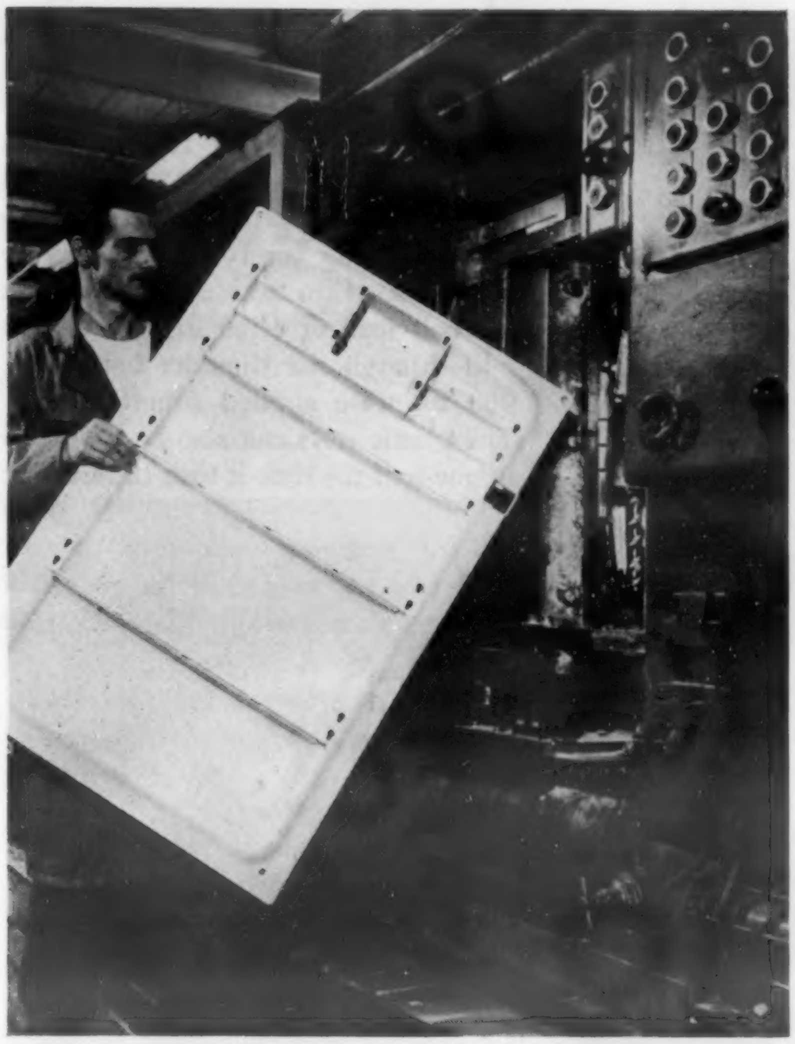
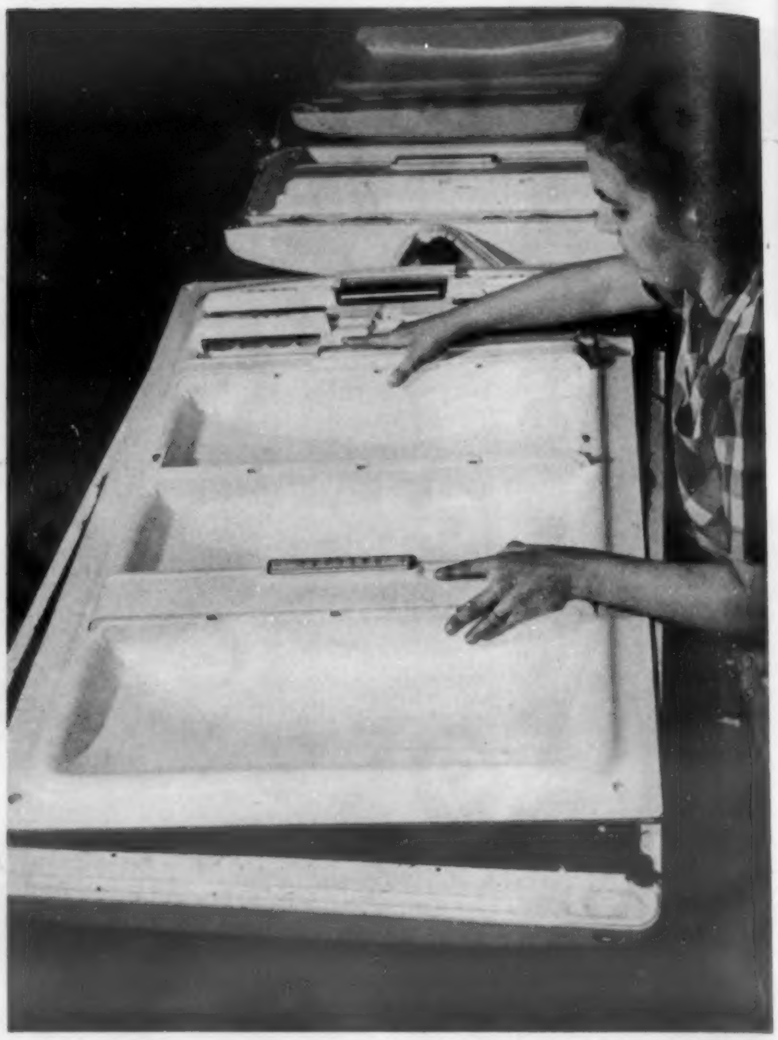
NYLON LAMP HOUSING

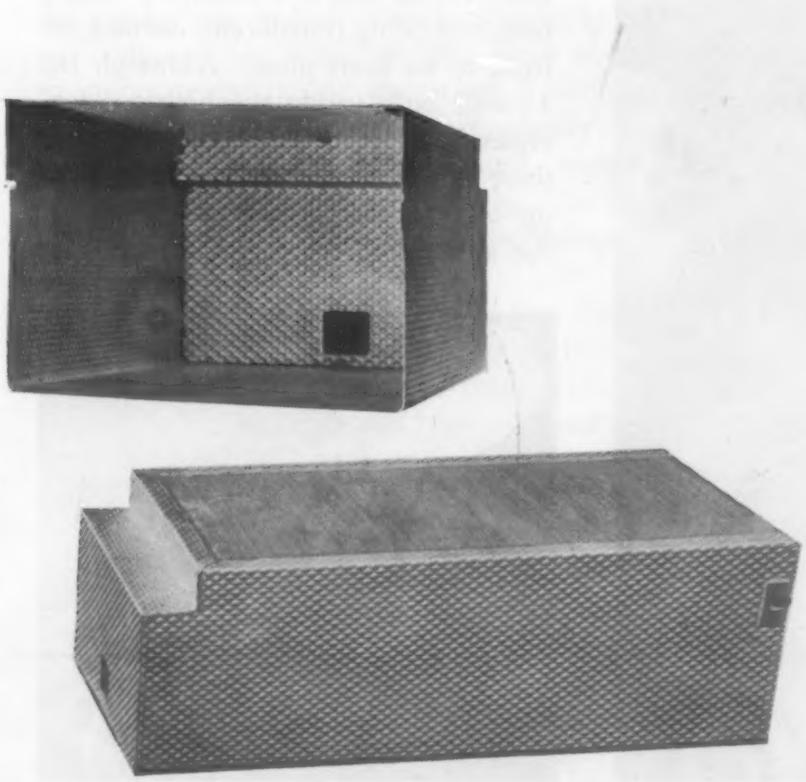
A translucent molded nylon tube, which forms a shatter-resistant lamp housing for the 1952 G-E automatic clothes washer, is being molded by the General Electric Chemical Div. Mounted under the top, the lamp illuminates the interior of the machine and aids in handling clothes. The housing has an exceptionally long draw, measuring 6 in. in length. It is $1\frac{1}{2}$ in. in dia, and has a wall thickness of 0.040 in. In evaluating materials for this application, glass was ruled out because of the breakage problem. Nylon has the necessary toughness, and being translucent, diffuses the light to an even glow. Although the 15-watt bulb inside the housing generates heat up to 250 F, nylon resists these high temperatures. It also holds up under the moisture conditions of the application.

Materials at Work





PLASTIC DOOR LINER The largest practical molded thermoplastic product now being made is a one-piece refrigerator door liner. The piece, complete with molded-in shelves, butter compartment and egg racks, weighs 7½ lb and has a projected area of 1240 sq in. The door is molded from Dow styrene copolymer for the Admiral Corp. It is the first production piece on the 300-oz Watson-Stillman injection molding machine. There are a number of advantages to the molded liner. It saves steel, titanium, cobalt and other materials necessary in porcelain enameled steel. It has greater acid resistance. The overall weight is reduced and better insulating qualities are secured with the plastic liner. Economies are realized in assembly, since shelves and accessory parts that were formerly assembled are now molded in. Amos Molded Plastics is producing the piece.

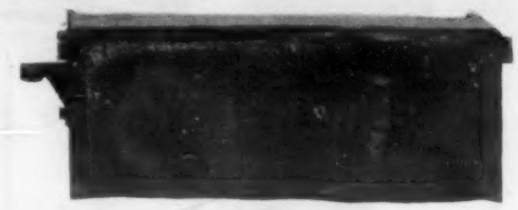


RIGIDIZED METAL ELECTRONIC CASES Auto pilot equipment used for military operations requires maximum protection from impact, pressure, shock and other damage. The problem facing metal fabricators of electronic cases for this special equipment was to find a material that would: (1) have high strength to insure complete protection for delicate contents; (2) have lightest weight for operating and transporting ease, as well as for conserving critical metals; (3) be fabricated without difficulty. Rigidized Metal, made by the Rigidized Metals Corp., has the desired qualities. It has increased strength-weight ratios, thus giving more lineal or square feet per pound of metal. Increased flexural rigidity adds high impact resistance to all outer surfaces. In the pattern used, metal thickness was reduced approximately 50%. This meant that less critical metal was needed. Fabrication was conducted without the use of special methods. The sharp corners of the cases were fabricated as easily with Rigidized Metal as with standard metals.

DUCTILE IRON FURNACE DOORS

An example of the improved service provided by ductile iron is illustrated by these two doors for steel forging furnaces used at the General Electric Co.'s River Works, West Lynn, Mass. These furnaces operate at interior temperatures as high as 1950 F, and as a result, the gray cast iron formerly used deteriorated quite rapidly from growth, warpage and scaling. A typical gray iron door is illustrated, obviously requiring replacement after one week's service. By contrast, the ductile iron door is shown after three months operation, and is good for considerably more. The average life of ductile iron doors is considered by General Electric to be around 300 days. The Thomson Laboratory of General Electric conceived the idea of using ductile iron for this application. The castings are produced by Taylor & Fenn Co., Hartford, Conn., licensed under the International Nickel Co., Inc. patents to produce the magnesium-containing material.

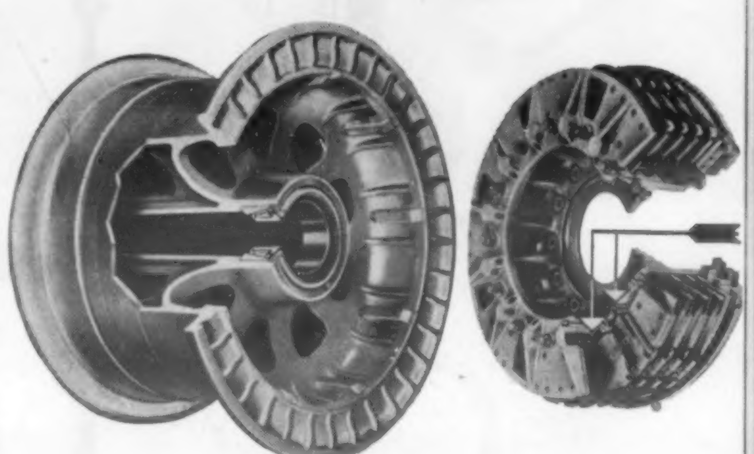
Gray Cast Iron

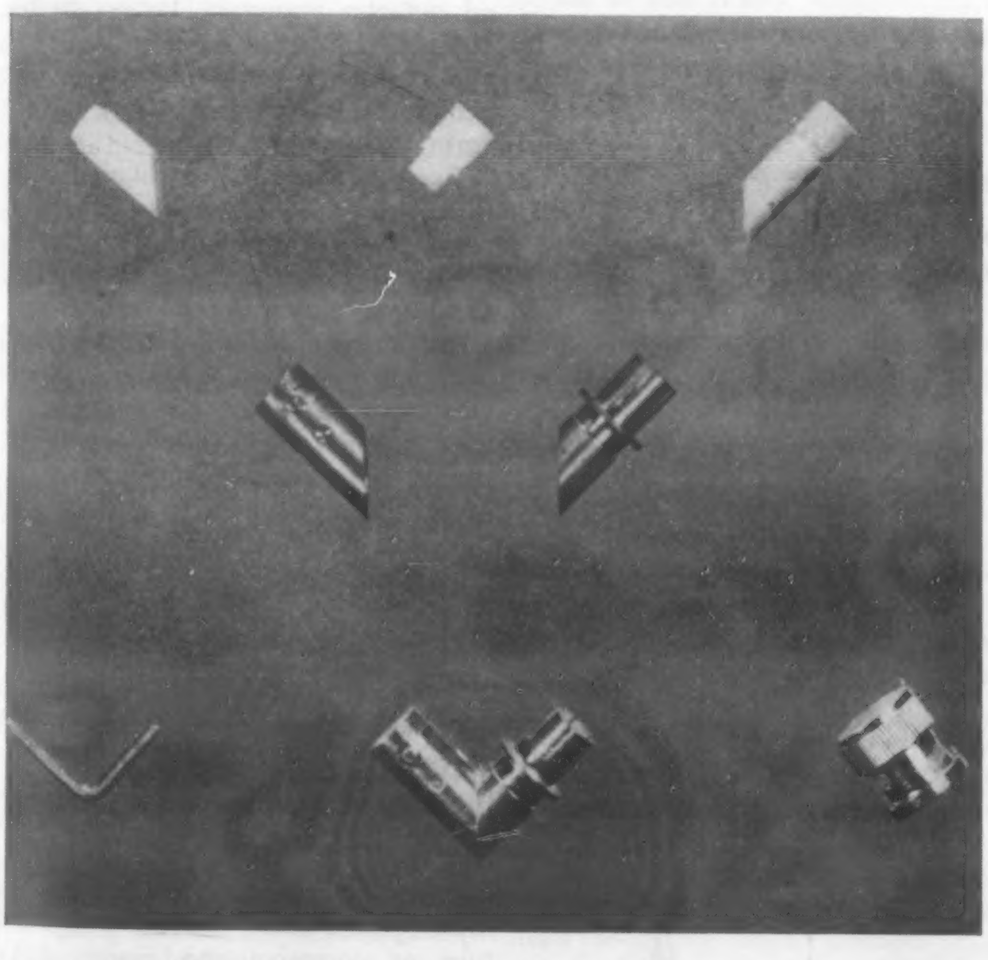


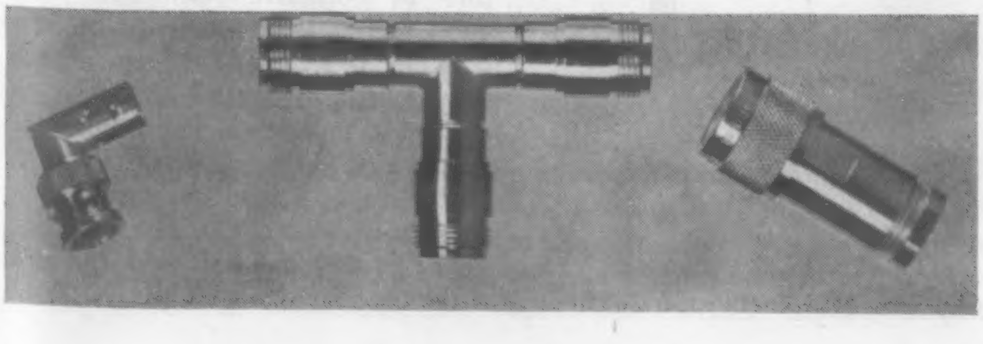
Ductile Iron

INCONEL "X" BRAKE SPRINGS

When a 150-ton bomber lands at 110 miles per hr, the temperature in the wheel brakes goes above 1000 F. The Segmented Rotor Brake, made by Bendix Products, uses linked segments of metal which revolve between stationary brake disks. The heat flows away in channels between the turning, segmented disks. The return springs, which force the brake apart when pressure is released, are located in the hot parts of the assembly. Bendix engineers decided that Inconel "X" was the only material that could be used in these springs. The particular wheel and brake shown are used on airliners now in commercial passenger service.





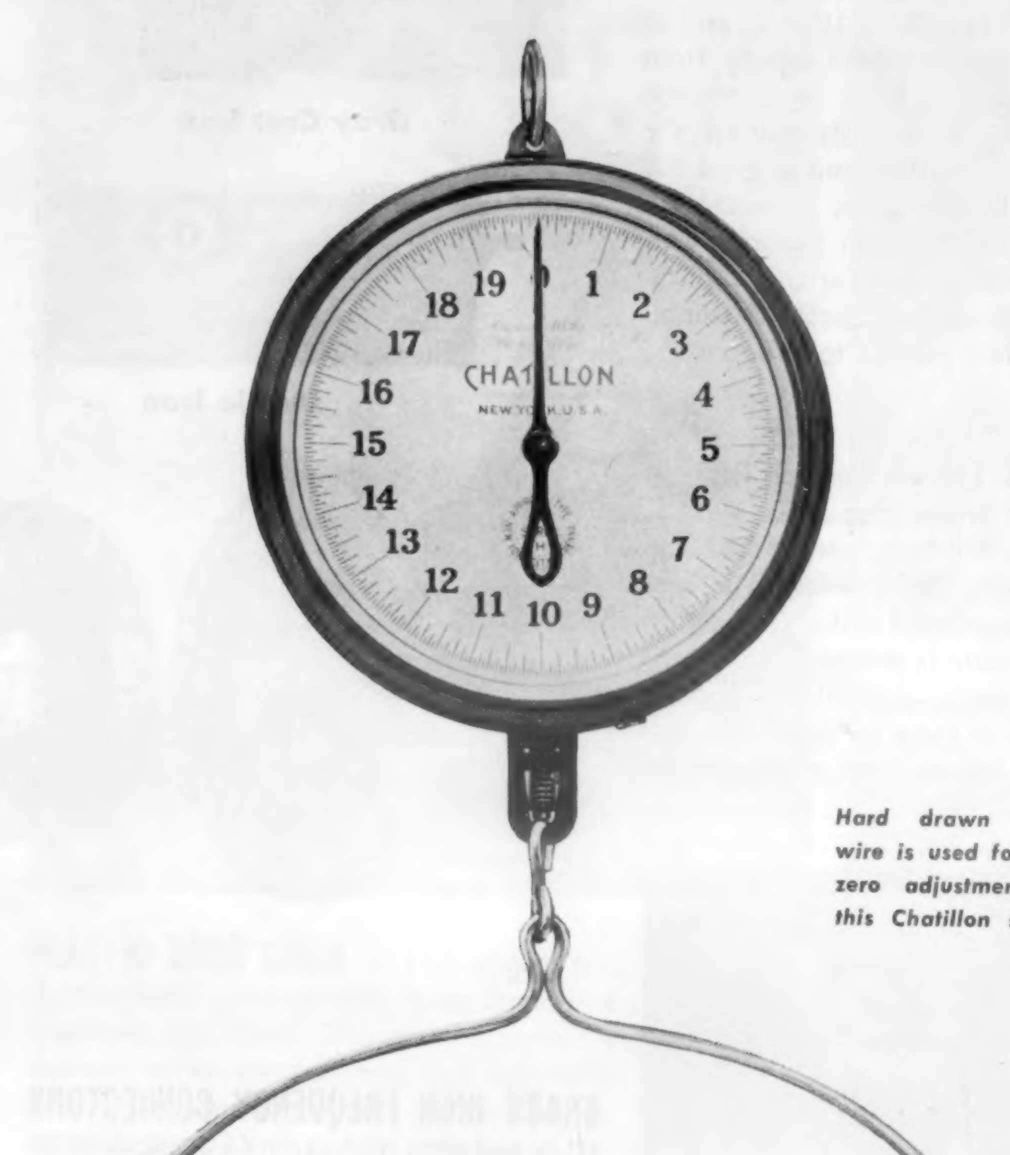


BRASS HIGH FREQUENCY CONNECTORS

High and ultra-high radio frequencies make it necessary to match the impedance of the solderless connectors, terminals and plugs to the coaxial cable used. Materials must be used which will not change physically or electrically with time. For these reasons, and because of their fabricating ease, copper and copper-base alloys are used. Bending a coaxial cable stretches the insulation and changes the electrical characteristics, for example. Precision right-angle, T and straight connectors are turned concentrically in screw machines from free machining brass. Center conductors are made of phosphor bronze or beryllium copper because of their spring properties and fatigue resistance. Since high frequency currents travel on the outside of the conductor, the lower conductivity of alloyed copper compared to the copper itself is offset by silver plating all parts. This plate not only increased electrical conductivity but, due to its close bond with the brass, withstands a 100-hr salt-spray test. The parts shown were made by the Industrial Products Co. of Danbury, Conn., from copper-base alloys furnished by the Bridgeport Brass Co.

How to Choose Spring Materials

This concluding portion of a two-part article explains how the cost and performance of a spring depends on the material used and how each material meets particular stress, accuracy, corrosion resistant and shock resistant requirements.



Hard drawn steel wire is used for the zero adjustment in this Chatillon scale.

by M. GERARD FANGEMANN, Manager, Spring Div., John Chatillon & Sons

● THE SELECTION OF a spring for any application would be simple if there were always sufficient space available and if cost were not a factor. Unfortunately, such conditions do not usually exist. The engineer must choose the cheapest spring that will do the job, and he must fit it into the smallest possible space. Corrosive environments and accuracy requirements must often be considered too. The article appearing previously (Jan. 1952) described the types of springs that are available, and pointed out the important factors to be considered in good design. This concluding article covers in detail the choice of material for any given spring application.

Spring materials are divided into three groups: (1) ferrous; (2) nonferrous; (3) special alloys. Under these headings there are 12 important alloys which can be used satisfactorily for practically all spring applications. There are, of course, other alloys that are used for a few specialized applications. The engineer should study carefully the properties of the 12 most widely used alloys, however, before specifying the material for any spring.

Ferrous Metals

Steel is the most common spring material. It is used in compositions varying from high carbon music wire to low carbon, hard-drawn spring steel, and is available in wire, strip and special shapes. Steel is usually the best bet unless: (1) the spring must operate under unusual temperature or corrosive conditions; (2) good electrical conductivity or freedom from magnetic effects are required; (3) drift and hysteresis errors must be kept small. Under these special conditions, nonferrous or special alloys should be considered.

Hard-drawn steel—The cheapest steel spring material and the one with the lowest strength is hard-

drawn steel wire. It is made in the same way as music wire, but less care is taken in processing it and in maintaining uniform chemical composition. Cold working gives the wire all its spring properties. Although the modulus of elasticity and the modulus of rigidity are the same as those of music wire, the elastic limit is considerably less. Hard-drawn wire is recommended for coil springs where accuracy is not important and the maximum stresses are low. The zero adjustment mechanism in a scale is a typical application. No great accuracy is needed here, and since sufficient space for the spring is available, the stresses can be made low. The hard-drawn steel spring does the job in the scale for the lowest possible price.

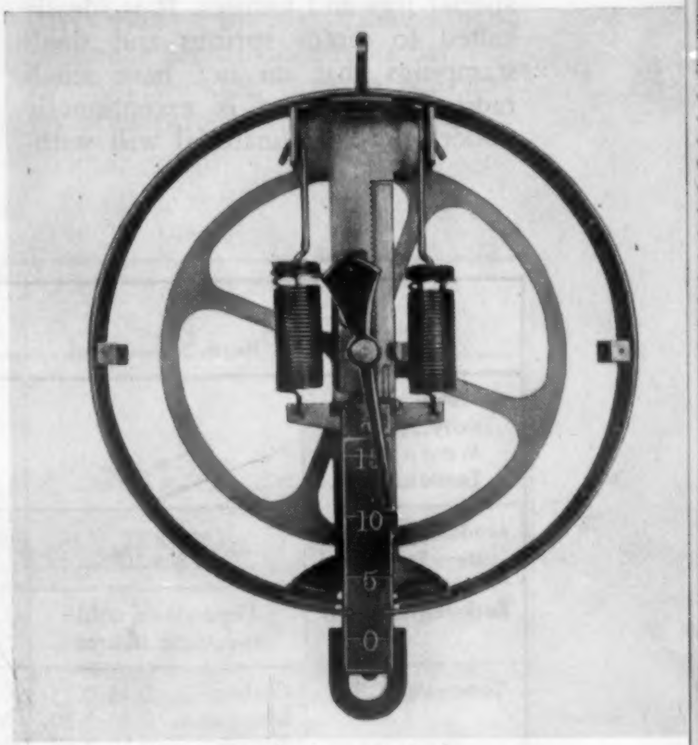
Oil-tempered steel—The spring material used for most ordinary applications is oil-tempered carbon steel. This is a high strength steel of uniform composition and temper. It is cold drawn to the desired size and then heat treated by a continuous tempering method. Springs are coiled and formed from this hardened material. A low temperature stress relief is all that is required after processing. This final heat treatment (½ hr at 450 to 650 F) relieves the stresses set up in coiling and hooking. Oil-tempered steel is moderately priced and is an excellent material for springs without severe bends, where endurance requirements are not drastic. Springs for precision instruments in which temperature changes are not important are typical applications. Illustrated is a precision weighing scale with oil-tempered steel springs. These springs must be capable of withstanding high stresses and shock loads.

Music Wire—Small springs subjected to extremely high stresses and sudden shocks are often made of music wire. This is a high carbon cold-drawn spring steel. The surface finish is excellent, since a thin coating of tin remains from the drawing operations. Consequently, it can be plated easily without the usual cleaning operations. Music wire is relatively expensive, however, and is only used where the loading and fatigue conditions warrant it. The music wire spring on the outside of the scale cylinder shown acts as a shock absorber when the load is suddenly released from the scale. The internal spring, on the other hand, is oil-tempered steel, which fulfills the weighing requirements. The electrical switch illustrated required extremely accurate springs operating at very high stresses. There was not enough room to use a cheaper material so that it was necessary to employ high tensile strength music wire, carefully plated, to produce satisfactory springs.

Chromium Vanadium Steel—Springs that are required to withstand a large number of stress cycles are often made of chromium vanadium steel. This is a medium carbon steel with chromium and vanadium added to increase the hardness and tensile strength. Chromium vanadium steel is used mainly for valve springs and other heavy duty springs. The springs must be free from surface marks and seams, and must have uniform internal structure. The steel is usually supplied in the annealed state for large capacity springs, and in the hardened condition for small wire size springs. When severe bends are required, however, springs are usually formed from annealed stock and hardened afterwards. This increases the price, of course, and every effort should be made to maintain the proper radii on hooks and ends to eliminate extreme stresses.

Stainless Steel—The most commonly used stainless steel is type 302, hard-drawn. This material is used where corrosion resistance is required. Although the cost of stainless is high, stainless steel springs are not necessarily more expensive than springs made of plated music wire. Besides being corrosion resistant, stainless steel springs are able to withstand elevated temperatures without losing their elasticity. Good appearance is another advantage, since the bright finish imparted to stainless in the drawing operations is retained after the post-forming stress releaving treatment. This stress relief consists of heating to about 750 F for ½ hr. Cadmium or lead coatings on stainless steel wire should be removed prior to this stress relief.

Clock Spring Steel—For applications requiring high strength and only moderate forming, blue-tempered clock spring steel is used. This is a high carbon steel, obtained in the hardened condition. A low temperature stress relief is all that is required after the springs are formed. The tendency today is to use this material in place of annealed spring steel to eliminate costly heat treating operations which usually require



Precision weighing scale is a typical application of oil-tempered steel springs. Temperature changes are not important here.

Music wire spring on the outside of this scale acts as a shock absorber. The internal weighing spring is made of oil tempered spring steel.

special jigs and fixtures. It is ideally suited to motor springs and small stampings that do not have small radii. The surface is exceptionally smooth, and the material will withstand high stresses over a large number of cycles.

Nonferrous Metals

Since steel in any form is unsuitable for many spring applications, some nonferrous spring alloys have been developed. These nonferrous alloys are used primarily for their electrical conductivity, nonmagnetic

Properties of

	Hard-Drawn Steel	Oil-Tempered Spring Steel	Music Wire	Chromium-Vanadium Spring Steel	Type 302 Stainless Steel
Modulus of Elasticity (Young's Modulus)—Tension, Psi	30 x 10^6	30 x 10^6	30 x 10^6	29 x 10^6	28 x 10^6
Modulus of Rigidity—Torsion, Psi	11.5 x 10^6	11.5 x 10^6	12 x 10^6	11.2 x 10^6	10 x 10^6
Rockwell Hardness	Depends on cold reduction of area	C-40 to C-48	C-45	C-45	C-42 to C-47
Composition, %	Carbon 0.45–0.75 Manganese 0.60–1.20 Silicon 0.10–0.50 Phosphorus 0.045 max Sulfur 0.050 max	Carbon 0.55–0.75 Manganese 0.80–1.2 Silicon 0.10–0.30 Phosphorus 0.045 max Sulfur 0.050 max	Carbon 0.70–1.0 Manganese 0.20–0.60 Silicon 0.12–0.30 Phosphorus 0.03 max Sulfur 0.03 max	Carbon 0.56–0.60 Manganese 0.60–0.90 Phosphorus 0.045 max Sulfur 0.045 max Chromium 0.80–1.10 Vanadium 0.15 min	Carbon 0.08–0.20 Chromium 17–19 Nickel 8–10
Elastic Limit in Tension	60% of ten str	85% of ten str	60% of ten str	90% of ten str	70% of ten str
Elastic Limit in Torsion	45% of ten str	45% of ten str	45% of ten str	70% of ten str	50% of ten str
Tensile Strength, Psi	Dia (In.) / Min / Max 0.028 260,000 310,000 0.105 200,000 242,000 0.177 180,000 220,000 0.312 160,000 200,000	Dia (In.) / Min / Max 0.032 275,000 310,000 0.105 220,000 255,000 0.172 195,000 225,000 0.312 178,000 208,000	Dia (In.) / Min / Max 0.028 314,000 376,000 0.072 300,000 330,000 0.120 268,000 298,000 0.156 255,000 285,000	Dia (In.) / Min / Max 0.032 280,000 300,000 0.105 250,000 275,000 0.207 215,000 235,000 0.312 200,000 220,000	Dia (In.) / Min / Max 0.028 289,000 316,000 0.072 250,000 280,000 0.156 220,000 250,000 0.250 180,000 205,000
Temperature Coefficient of Modulus of Rigidity	......	0.00014/° F	0.00014/° F	0.00014/° F	0.00022/° F
Temperature Coefficient of Modulus of Elasticity	......	......	......	−146 x 10^{-6}/° F	......
Heat Treatment	Internal stress relief, 500 F	Internal stress relief, 500 F	Internal stress relief, 470 F	......	Internal stress relief, 600 F
Density	0.284 lb/cu in.	0.284 lb/cu in.	0.284 lb/cu in.	0.284 lb/cu in.	0.290 lb/cu in.
Electrical Resistivity	......	......	11 microhm-cm	......	72 microhm-cm
Electrical Conductivity (Copper Standard)	......	......	12.3%	......	2.4%
Coefficient of Thermal Expansion (68 F)	......	......	0.0000064/° F	0.0000064/° F	0.0000096/° F
Uses	Cushion and bed springs, wire forms and toy springs. Low stress applications.	Weighing scales. Usual normal stress applications.	Switches, tools and mechanical adjustment systems. Most commercial applications.	Valve, recoil, die and railroad car springs. For applications to withstand impact and shock.	Valve springs (noncyclic) and chemical flowmeters. Most applications where corrosion resistance is required.

properties and special corrosion resistance.

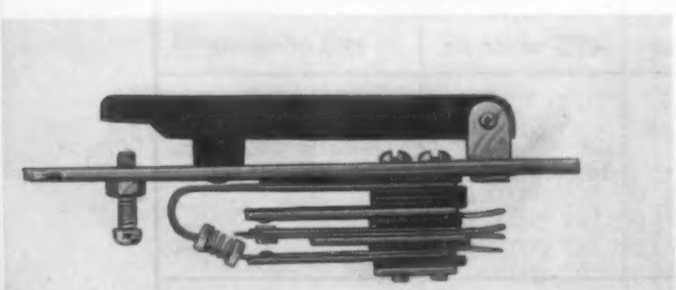
Brass—One of the most commonly used materials is spring brass. Brass is satisfactory for low stress applications at normal temperatures where electrical conductivity is important. Spring brass wire gets its hardness by cold drawing. It has fairly good corrosion resistance and is readily plated.

Phosphor Bronze — Like brass, phosphor bronze obtains its hardness by cold working through the dies. Its principal use is also for applica-

Spring Materials

Clock Spring Steels	Phosphor Bronze-A	Spring Brass	Beryllium Copper	Iso-Elastic	Inconel	Inconel-X
30 x 10^6	15 x 10^6	15 x 10^6	16 x 10^6	26 x 10^6	31 x 10^6	31 x 10^6
......	6.25 x 10^6	5.5 x 10^6	6.7 x 10^6	9.2 x 10^6	11 x 10^6	11 x 10^6
C-46 to C-52	B-90 to B-100	B-90	C-35 to C-42	C-30 to C-36	C-30 to C-40	C-30 to C-40
Carbon 0.90–1.05 Manganese 0.30–0.50	Tin 3.5–3.8 Phosphorus 0.03–0.35 Lead 0.05 max Iron 0.10 max Zinc 0.30 max Antimony 0.01 max Copper Rem	Copper 64–72 Zinc Rem	Copper 98 Beryllium 2	Chromium 8 Nickel 36 Molybdenum 0.5 Iron Rem	Nickel 78.5 Chromium 14 Copper 0.2 Iron 6.5	Nickel 70 min Chromium 14–16 Iron 5–9 Titanium 2.25–2.75 Columbium 0.7–1.2 Others Rem
80% of ten str	75% of ten str	40% of ten str	75% of ten str	60% of ten str	75% of ten str	75% of ten str
......	55% of ten str	35% of ten str	50% of ten str	35% of ten str	45% of ten str	45% of ten str
250,000–325,000 Used in strip form	100,000–150,000 (average)	100,000–130,000 (average)	160,000–200,000	170,000	140,000–175,000	140,000–175,000
......	0.00022/° F	......	......	......	......	......
......	-200×10^{-6} to -220×10^{-6}/° F	-216×10^{-6}/° F	-194×10^{-6}/° F	-11×10^{-6} to -8×10^{-6}/° F	......	......
Internal stress relief, 500 F	Internal stress relief, 500 F	Internal stress relief, 500 F	Depends on conductivity characteristics desired	Internal stress relief, 750 F	Internal stress relief, 900 F	Internal stress relief, usually 900 F
......	0.320 lb/cu in.	0.309 lb/cu in.	0.297 lb/cu in.	0.292 lb/cu in.	0.307 lb/cu in.	0.307 lb/cu in.
......	9.58 microhm-cm	6.6 microhm-cm	8.31 microhm-in.	88 microhm-in.	......	124 microhm-cm
......	18%	26%	22%	......	......	......
......	0.0000099/° F	0.0000112/° F	0.0000092/° F	0.000004/° F	0.0000064/° F	0.0000064/° F
Motor and clock springs. High stress applications.	Switches, contacts, relays and valves. Electrical applications.	Switches and contacts. Electrical applications below 120 F.	Brush springs, switches and fuse clips. Electrical applications.	Temperature compensated scales, aircraft instruments and instruments where electrical conductivity is not important.	Marine and aircraft engines. High temperature applications.	Jet engine springs. Extremely high temperature applications.

Atlas Car & Manufacturing Co. weighing mechanism uses chromium-vanadium steel springs. These springs are subject to high stresses and shock.



Music wire is used for the spring in this switch made by the Roanwell Corp. Stresses are high and the spring withstands constant cycling.

tions requiring good conductivity and corrosion resistance. It should not be used at temperatures above 120 F or in salt atmospheres.

Beryllium Copper—An alloy which has come into wide use is beryllium copper. This material has good corrosion resistance, is nonsparking and nonmagnetic, has excellent electrical conductivity, and shows high strength and exceptionally good fatigue life. The disadvantage to its use is the critical and time-consuming heat treatment it requires. For certain applications, however, there is no substitute for beryllium copper.

By changing the heat treatment, the properties of beryllium copper can be varied considerably. The tensile strength increases with prolonged heat treatment at low temperatures. For example, the tensile strength after 3 hr at 700 F is 130,000 psi, while the same alloy, after 3 hr at 550 F, has a tensile strength of 180,000 psi. The electrical conductivity, on the other hand, increases with prolonged treatment at high temperatures. Beryllium copper is stable at normal temperatures, and is suitable for instrument spring applications.

Special Alloys

In some applications, neither the steel nor the copper alloy spring materials are suitable. Extreme accuracy requirements or special temperature or corrosive conditions can often be handled only with special high nickel alloys.

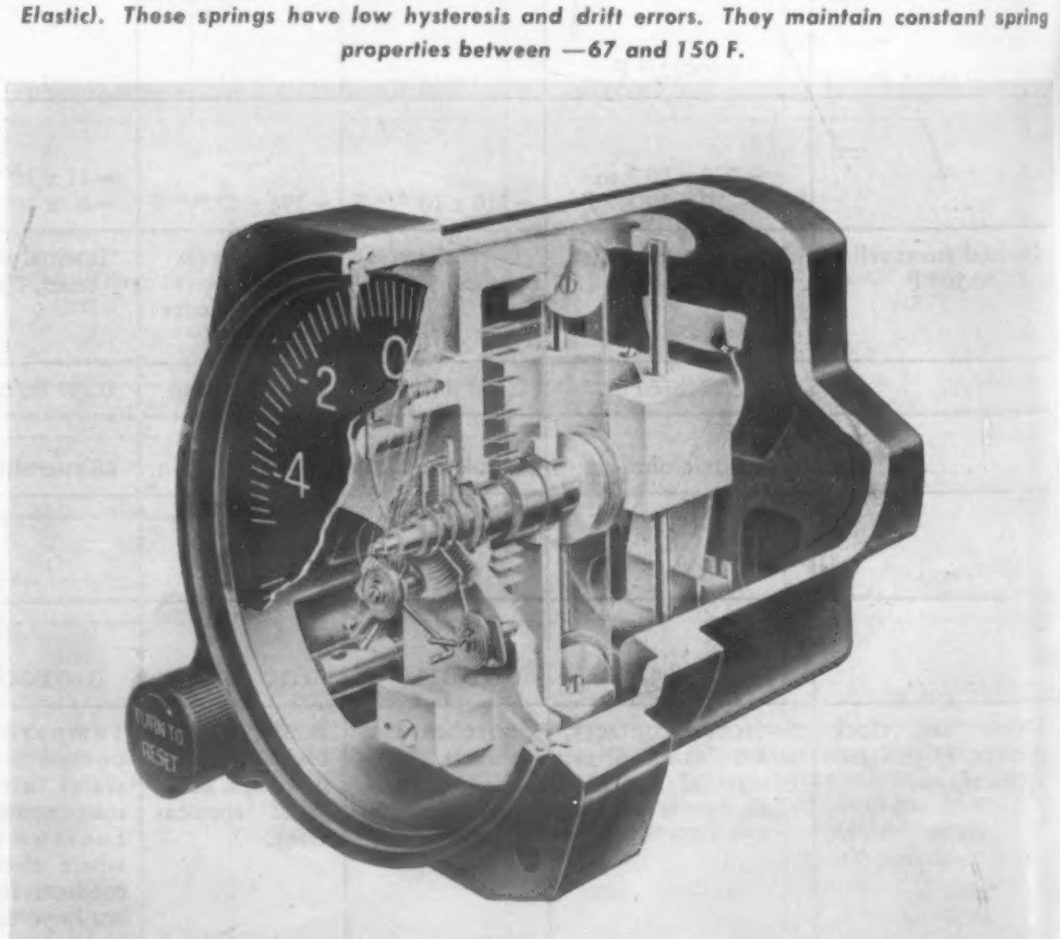
Iso Elastic—A nickel-chromium alloy that is rapidly becoming popular is Iso Elastic. The 36 nickel, 8% chromium composition offers good corrosion resistance. At the same time, the alloy has a low temperature coefficient of the modulus of elasticity, which makes it suitable for applications where spring performance cannot vary significantly with the temperature. It is used in precision instruments, for example. The drift error is less than 0.02% of deflection, and the hysteresis error is less than 0.01% of deflection. Iso Elastic is not heat treatable, and receives most of its spring properties by cold reduction. The material is usually reduced by 93½% in area. It is coiled and formed in the hardened condition. A low temperature stress relief treatment is required after forming. This is usually carried out at 750 F for ½ hr.

A typical use of this alloy is in temperature compensated springs. The Bendix accelerometer is used throughout the usual aircraft temperature range, —65 to 150 F. The spring maintains uniformity in loading characteristics, and has very small hysteresis and drift errors.

Inconel—Containing 77 nickel and 15% chromium, Inconel is a high strength alloy that is applicable for high temperature uses. The high nickel content gives it excellent corrosion resistance over wide ranges of alkalinity and acidity. Inconel can be used up to 700 F. Its greatest strength is between 500 and 700 F, but it can also be used at lower temperatures. A 1-hr heat treatment at 900 F is used to stress relieve springs.

Inconel X—An alloy similar to Inconel is Inconel X. It can be used for springs operating at even higher temperatures, up to 1200 F. Inconel X springs are advantageous in jet applications where such extreme temperatures are common.

Bendix Accelerometer is a typical application of temperature compensated springs (Iso Elastic). These springs have low hysteresis and drift errors. They maintain constant spring properties between —67 and 150 F.



(Republic Aviation Corp.)

Titanium and its Alloys

MATERIALS & METHODS MANUAL No. 82

This is another in a series of comprehensive articles on engineering materials and their processing. Each is complete in itself. These special sections provide the reader with useful data on characteristics of materials or fabricated parts and on their processing and applications.

MAY 1952

by John L. Everhart, Associate Editor, Materials & Methods

The distinctive characteristics of titanium are becoming more fully understood and, as a result, suitable working procedures are being developed more rapidly. Although a number of problems remain unsolved, several organizations are now fabricating titanium and some of its alloys commercially. This Manual discusses the present status of this rapidly changing field. Topics included are:

- ***Engineering Properties***
- ***Forming and Machining Characteristics***
- ***Cleaning and Finishing***
- ***Heat Treatment***
- ***Present and Future Uses***
- ***Weldability***

In the first burst of enthusiasm accompanying the announcement of its properties, titanium was called "the wonder metal" and billed as the successor to aluminum and the stainless steels. Sober reflection, however, indicates the over-enthusiasm of such claims. Titanium will find its place as a useful member of the metal community when its characteristics and properties are more fully evaluated. It will replace aluminum in some applications and stainless steels in others but there will still be plenty of uses for both of these materials. In this connection, the following remarks which express the general opinion of the copper industry should assist in gaining the proper perspective.

Copper has been in competition with other materials since the dawn of history. Each time a newer metal appears, copper is threatened. Twice in the present century, copper alloys have gone to war, almost completely abandoning the civilian market. Substitutes took their place and claims were made that copper had been permanently replaced but, when the wars ended, the copper alloys regained their normal markets without difficulty. The future of copper will depend not on other metals but on its availability.

Certainly the future of titanium will depend, not on other metals, but on the ability of the producers to overcome the handicaps of batch operation leading to non-uniform composition, to produce shapes of uniform quality, and to develop suitable fabricating methods at prices which will make the metal truly competitive with other constructional materials in a civilian economy. Prices will have to be much lower than the present figures if titanium is to realize its full potentialities.

Production of titanium had reached an estimated 700 tons per year in 1951. This is a remarkable achievement when it is considered that the Bureau of Mines pilot plant was announced in 1946 and commercial production started in 1948 with a plant having a rated capacity of 100 lb per day, but it is a far cry from the normal production rates of the metals with which titanium will be in competition. As a matter of fact, the yearly production of metallic cadmium is about 4000 tons and this is hardly a major metal. It is doubtful whether 1000 tons of titanium have been produced since the beginning of commercial operation, and because of this fact, the available metal has been spread rather thinly over research and industrial fields.

Information on such factors as forming properties, machinability and joining of titanium is quite limited, and many contradictory statements have been made. Alloy development can be said to be in the very early stages of the art. Many alloys have been studied, more or less thoroughly, and a number are available on a commercial basis. Information on certain of the more common properties has been published but very little has been reported on their fabricating characteristics. This is not surprising in the present state of alloy development. One manufacturer stated that he would not spend the money necessary to learn to work titanium alloy sheet until he was satisfied that composition could be held within commercial limits and sheet quality could be maintained.

Since the development of suitable fabricating techniques is the result of considerable experience with a material, it will probably be some time before procedures are more or less standardized. Thus, methods recommended today are certain to be modified or abandoned in the future in favor of more suitable procedures. The information given in the following pages will assist the materials engineer in avoiding some of the pitfalls in the working of titanium but should be considered as a report of developmental rather than production line methods.

Commercial Grades and Alloys

Surface conditioning a titanium alloy billet at the Watervliet plant of Allegheny-Ludlum for the Titanium Metals Corp.

Commercial titanium is produced at present by the Kroll process or its modifications. Iodide titanium is produced on a small scale but has no present commercial significance. Several other procedures, notably electrolytic methods, are still in the development stage.

The titanium obtained by the Kroll process is in the form of sponge and must be melted or compacted by some other means to obtain a massive product for further working. Currently, arc and induction melting procedures are employed commercially. A combination of hot and cold working methods is employed to produce the desired shape after melting. Commercial titanium is produced as plate, sheet, strip, rod, forgings, drawn tubing, wire and special shapes. The titanium cladding of low-carbon steel has been reported also. Because of the reactivity of the metal with gases and mold materials at elevated temperatures, suitable methods for the production of commercial castings have not been devised although developmental work is proceeding in a number of organizations.

Recently, the Interstate Commerce Commission has issued schedules for the shipment of titanium by railroad freight while the release of schedules for truck shipments is expected shortly. Until this development occurred, titanium shipments had to be made by mail or express, a suitable method for small lots but hardly attractive as a commercial procedure.

Several grades of commercial ti-

tanium are currently in production, their properties varying with the purity of the material, especially with the nitrogen, oxygen and carbon contents. Of these three elements, nitrogen has the greatest effect on the properties and carbon the least. Society, Governmental and private specifications are being prepared for these materials.

The ASTM has in preparation three tentative standards for titanium. One deals with iodide titanium as deposited and covers the minimum titanium content and the maximum content of certain other elements. It includes hardness requirements also. A second covers massive titanium in ingot form, specifying the minimum titanium content, the maximum content of certain impurities and the maximum hardness of each of four grades. The third covers the same four grades of titanium in the form of annealed mill products and includes, in addition to the chemical specifications, permissible ranges of mechanical properties for each grade. These standards are still being considered by the committee charged with their development, but it is expected that they will be issued in tentative form later this year.

The Aeronautical Material Specifications Div. of the SAE has almost completed a specification which will cover a commercially pure grade of annealed titanium sheet having a minimum tensile strength of 80,000 psi.

Although a great many alloy combinations have been investigated in the laboratory, only a few are available commercially at present. These may be divided roughly into two groups:

1. Those developed primarily for applications in flat form include Ti-100A, Ti-150B, RC-130A, MST 2.5 Fe-2.5V, and MST 2 Al-2 Fe.

2. Those developed as forging al-

Commercial Forms Available

Designation	Sheet	Strip	Plate	Wire	Bars	Rod	Forging Billets	Forgings	Welded Tubing
Commercial Titanium	√	√	√	√	√	√	√	√	√
Titanium Alloys*									
MST 2 Al-2 Fe	√	√			√		√	√	
RC-130 B					√		√	√	
MST 3 Al-5 Cr					√		√	√	
Ti-150 A					√		√	√	
Ti-175 A					√		√	√	
Ti-150 B	√	√	√						
Mst 2.5 Fe-2.5 V	√	√			√		√	√	
RC-130 A	√								

** See composition table.*

Composition of Commercial Titanium and Titanium Alloys

Designation	Producer	Nominal Composition, %									
		C	O	N	Al	Cr	Fe	Mn	V	Mo	W
Commercial Titanium											
Ti-55 A	Titanium Metals	0.02 max	Trace	0.02	..	..	0.10	..	..	..	0.02 max
Ti-75 A	Titanium Metals	0.02 max	Trace	0.02	..	..	0.10	..	..	..	0.02 max
RC-55	Rem-Cru	0.2 max	(a)	(a)	..	..	(a)	..	..	..	..
MST Grade III	Mallory-Sharon	0.25 max	..	..	..	..	..	..	..	..	..
RC-70	Rem-Cru	0.2 max	(a)	(a)	..	..	(a)	..	..	..	..
MST Grade IV	Mallory-Sharon	0.3–0.8	..	..	..	..	..	..	..	..	..
Ti-100A	Titanium Metals	0.02 max	Trace	Trace	..	..	0.1	..	..	..	0.02 max
Titanium Alloys											
Aluminum-Iron Alloy MST 2 Al-2 Fe	Mallory-Sharon	0.5	..	..	2	..	2	..	..	..	..
Aluminum-Manganese Alloy RC-130 B	Rem-Cru	0.2 max	(a)	(a)	4	..	(a)	4	..	..	..
Chromium-Aluminum Alloy MST 3 Al-5 Cr	Mallory-Sharon	0.5	..	..	3	5	..	..	..	..	..
Chromium-Iron Alloys											
Ti-150 A	Titanium Metals	0.02	0.25	0.02	..	2.7	1.3	..	..	..	0.02 max
Ti-175-A	Titanium Metals	0.02	0.5	0.04	..	3.0	1.5	..	..	..	0.02 max
Chromium-Iron-Molybdenum Alloy Ti-150 B	Titanium Metals	0.02 max	Trace	0.02	..	5	5	..	..	5	0.02 max
Iron-Vanadium Alloy MST 2,5 Fe-2.5 V	Mallory-Sharon	0.5	..	..	..	..	2.5	..	2.5	..	..
Manganese Alloy RC-130 A	Rem-Cru	0.2 max	(a)	(a)	..	..	(a)	7	..	..	..

(a) Few hundredths to few tenths.

NOTE: The Mallory-Sharon Titanium Corp. has changed the designations of its alloys as follows:

Old	*New*
L 2851	MST Grade III
L 2749	MST Grade IV
L 2748	MST 3 Al-5 Cr
L 2841	MST 2.5 Fe-2.5 V
L 2852	MST 2 Al-2 Fe

loys including Ti-150A, Ti-175A, RC-130B and MST 3 Al-5 Cr.

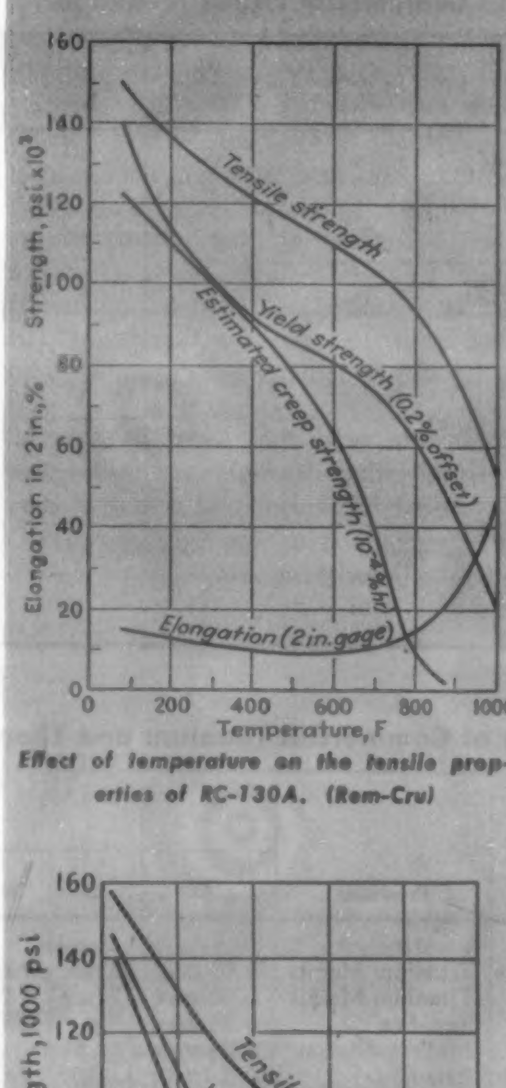
These alloys contain combinations of chromium, iron, aluminum, vanadium, molybdenum and manganese. Elements such as iron, chromium, vanadium, molybdenum and manganese tend to stabilize the high temperature modification (the beta phase) of titanium and to produce alloys which are hardenable by heat treatment. Aluminum, nitrogen and oxygen tend to strengthen the low temperature modification (the alpha phase). Some of the properties of the commercial alloys are included in accompanying tables and graphs.

Since the state of development of the alloys has not advanced sufficiently to justify the setting of standards, each producer currently lists his own alloys. Compositions of these materials are given in an accompanying table. There does not appear to be any logical method of classifying these alloys, although they are all two-phase materials and, therefore, they have been listed in the tables in alphabetical order based on the major alloying constituent. A more satisfactory procedure will probably appear when alloying has developed further.

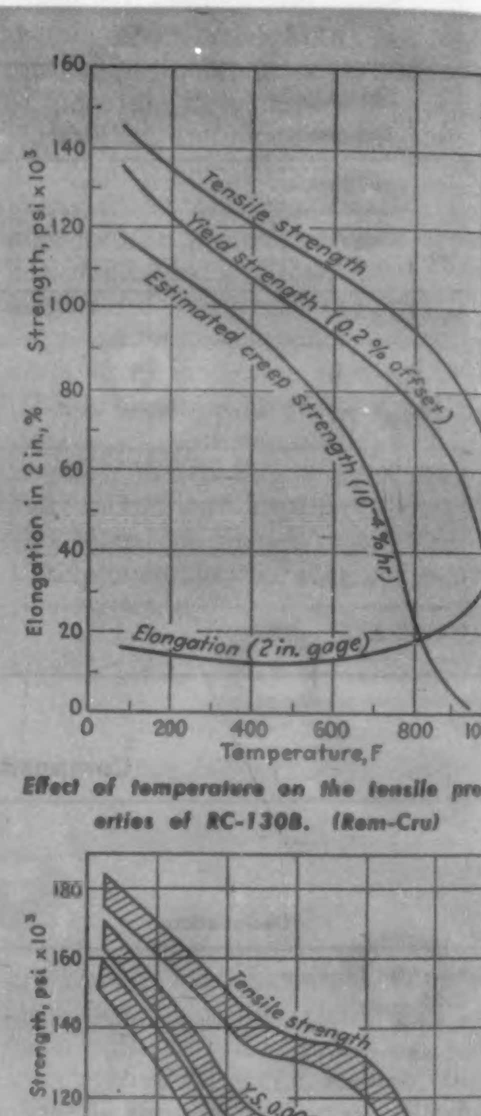
Engineering Properties

Some of the physical and mechanical properties of the various grades of commercial titanium are given in the accompanying tables and graphs. The melting point of the metal is higher than those of any of the metals that are used at present as constructional materials while the density is intermediate between those of aluminum and the stainless steels. The electrical resistivities of titanium and the stainless steels are similar. The modulus of elasticity is somewhat more than half that of the steels, and the coefficient of expansion is less than half that of the austenitic stainless steels.

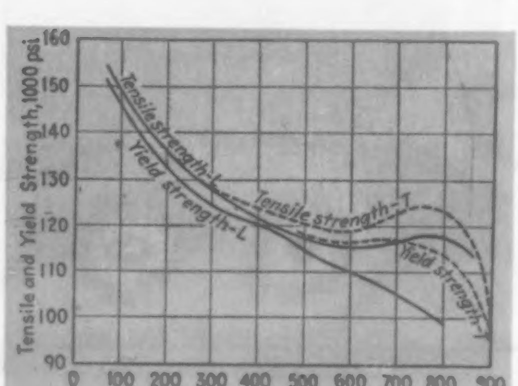
Titanium is a very active metal and readily dissolves carbon, oxygen and nitrogen. All three strengthen the metal, with oxygen and nitrogen having the most pronounced effects. Control of the content of these three elements is one of the problems in producing satisfactory ingots, a problem which has not yet been solved completely. Thus, there is considerable variation in the properties of different ingots of the commercial metal produced by a single organi-



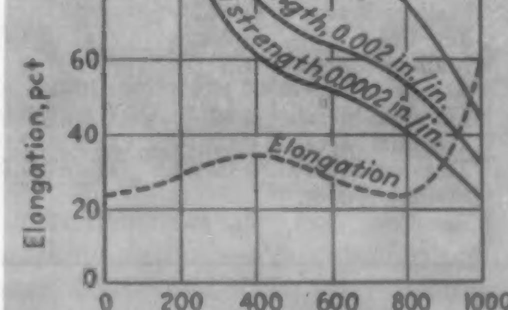
Effect of temperature on the tensile properties of RC-130A. (Rem-Cru)



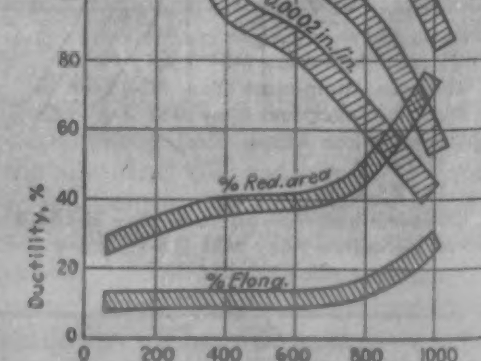
Effect of temperature on the tensile properties of RC-130B. (Rem-Cru)



Longitudinal and transverse strengths of Ti-150B annealed sheet. (Titanium Metals)



Effect of temperature on the tensile properties of Ti-150A. (Titanium Metals)



Effect of temperature on the tensile properties of MST3Al-5Cr. (Mallory Sharon)

Nominal Mechanical Properties

Commercial Designation*	Form	Condition	Yld. Str., 0.2% Offset, Psi	Ten. Str., Psi	Elong, % 2 In.	Red. of Area, %	Hardness	
							Rockwell	Brinell
Commercial Titanium								
Ti-55 A	Sheet and strip	Annealed	48,000	65,000	26.5	..	R_b80	...
Ti-75 A	Sheet and strip	Annealed	75,000	88,000	21	..	R_b90	...
	Plate	Annealed	68,000	85,000	21.5	..	..	219
	Wire	Annealed	72,000	83,000	22.5**	47.5	..	...
		Cold drawn, full hard	125,000	145,000	11.5**	37.5	..	...
	Forgings, hot-rolled bars	Annealed	60,000	80,000	25**	..	..	190
RC-55	Sheet, bar, plate	Annealed	65,000	75,000	25	55	R_a50–54	...
	Forgings	Annealed	65,000	75,000	15	30	R_a50–54	...
MST Grade III	Sheet	Annealed	72,000	80,000	25	55	R_a60	...
		Cold worked, 50%	110,000	125,000	12	30	R_a64	...
	Forgings	As forged	72,000	80,000	25	55	R_a62	...
RC-70	Sheet	Annealed	80,000	90,000	20	50	R_a54–58	...
		½ hard	105,000	120,000	12	35	..	...
	Forgings	As forged	80,000	90,000	15	30	R_a54–58	...
MST Grade IV	Sheet, 0.040 in.	Annealed 1 hr at 1300 F	85,000	100,000	18	15	R_a61	...
		Cold worked, 37%	120,000	130,000	6	14	R_a65	...
	Forgings	Hot forged, 80% reduction	75,000	80,000	18	50	R_a61	...
Ti-100 A	Sheet and strip	Annealed	95,000	110,000	17.5	..	R_b98	...
	Plate	Annealed	100,000	110,000	18.5	..	..	270
	Wire	Annealed	88,000	108,000	22.5**	47.5	..	...
		Cold drawn, full hard	160,000	190,000	12.5**	25	..	...
	Forgings, hot rolled bars	Annealed	88,000	102,000	20**	..	..	252
Titanium Alloys								
MST 2 Al-2 Fe	Sheet, 0.040 in.	Annealed 1 hr at 1300 F	..	140,000	14	..	R_a68	...
		Cold worked, 37%	..	180,000	6	..	R_a70	...
	Forgings	Hot forged, 80%	135,000	145,000	12	35	R_a68	...
RC 130 B	Bar	Annealed	140,000	150,000	20	40	..	...
	Forgings	As forged	130,000	150,000	15	30	R_c33–36	...
MST 3 Al-5 Cr	Forgings	Hot forged, 80% reduction	153,000	165,000	8	25	R_a71	...
		Furnace cooled	..	165,000	10	..	R_a73	...
Ti-150 A	Plate	Annealed	120,000 min	152,000	12 min	..	..	341
	Forgings, hot rolled bars	Annealed	120,000 min	150,000	15 min	..	..	341
Ti-175 A	Plate	Annealed	140,000 min	172,000	8 min	..	..	379
	Forgings, hot rolled bars	Annealed	140,000 min	170,000	10 min	..	..	379
Ti-150 B	Sheet and strip	Annealed	135,000 min	160,000	10	..	R_c35	...
	Plate	Annealed	135,000 min	160,000	10	..	..	322
MST 2.5 Fe-2.5 V	Sheet, 0.040 in.	Annealed 1 hr at 1300 F	125,000	135,000	10	..	R_a65	...
		Cold worked, 37%	170,000	175,000	2	..	R_a68	...
	Forgings	Hot forged, 80% reduction	105,000	130,000	12	35	R_a65	...
RC-130 A	Sheet	Annealed	130,000	150,000	25	35	R_c33–36	...

** See composition table.*
*** % elongation in 4 dia.*

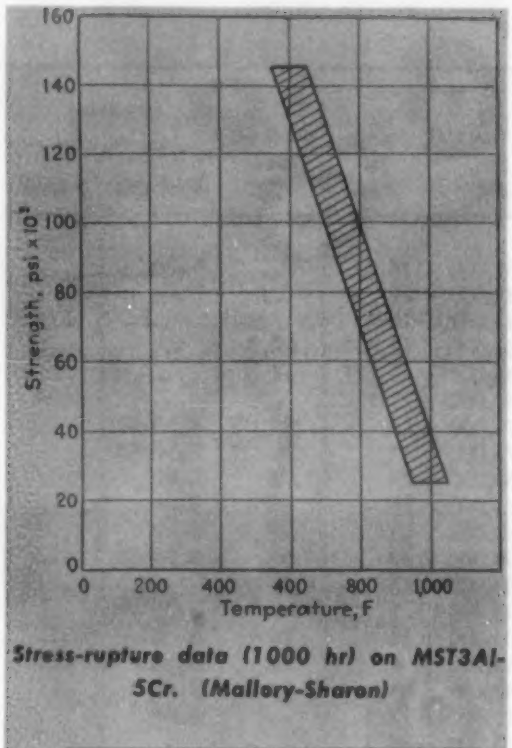
Nominal Physical Properties

Commercial Designation	Density, Lb/Cu In.	Melting Range, F	Thermal Cond., Btu/Hr/Sq Ft/Ft/°F at 212 F	Coef. of Exp, per °F	Specific Heat, Btu/Lb/°F	Elec Resist., Microhm-Cm	Elec Cond, % IACS	Mod of Elasticity, Psi
Commercial Titanium	0.16	3135	8–10	5.0×10^{-6}	0.13	61	3.1	15,000,000
Titanium Alloys*								
MST 2 Al-2 Fe	0.165	..	..	5.4×10^{-6}	..	118	1.5	17,000,000
RC-130 B	0.17	2910–3090	..	..	..	..	..	15,500,000
MST 3 Al-5 Cr	0.166	..	..	5.0×10^{-6}	..	140	1.2	17,000,000
Ti-150 A	0.166	..	8–10	5.0×10^{-6}	0.129	60	3.0	16,000,000
Ti-175 A	0.168	..	8–10	5.0×10^{-6}	0.129	60	3.0	16,000,000
Ti-150 B	0.168	..	8–10	5.0×10^{-6}	0.129	..	..	16,000,000
Mst 2.5 Fe-2.5 V	0.167	..	..	5.1×10^{-6}	..	78	2.2	15,000,000
RC-130 A	0.17	2550–2740	..	..	..	..	..	15,600,000

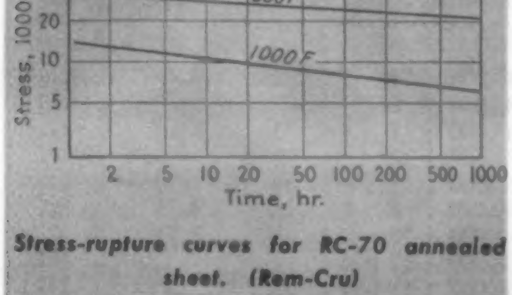
** See composition table.*

zation. There are several organizations producing massive titanium from several sources of sponge and the properties of commercial metal can be quite different if it is obtained from different sources. There are several materials listed as commercial titanium which differ in carbon content and probably also in nitrogen and oxygen content, although the latter are seldom reported.

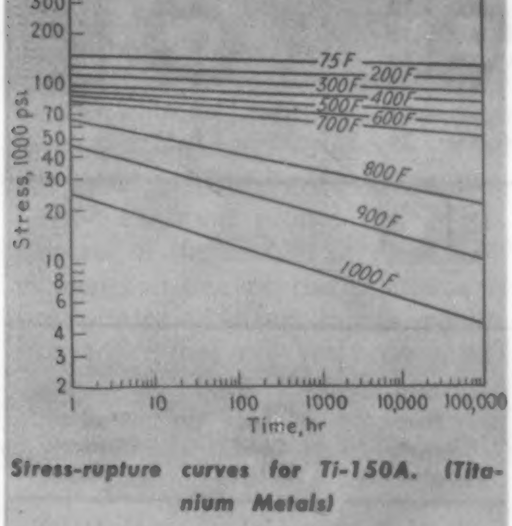
The high melting point of titanium led to the thought that the metal would be suitable for high temperature applications. Unfortunately this



Stress-rupture data (1000 hr) on MST3Al-5Cr. (Mallory-Sharon)



Stress-rupture curves for RC-70 annealed sheet. (Rem-Cru)



Stress-rupture curves for Ti-150A. (Titanium Metals)

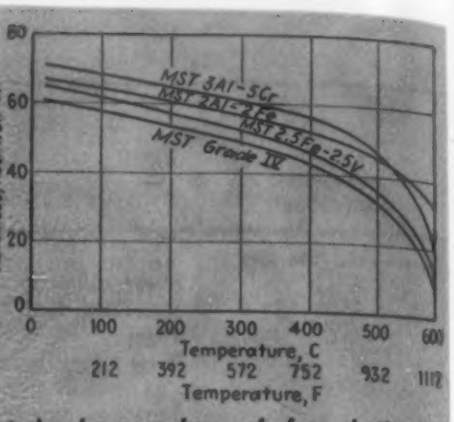
is not the case. Both oxygen and nitrogen are absorbed by titanium at high temperatures, and prolonged exposure results in permanent embrittlement of the metal. At temperatures above 600 F hydrogen can be absorbed in large quantities and may cause embrittlement also. In contrast with the embrittlement caused by oxygen and nitrogen, that caused by hydrogen can be removed by heating in a vacuum, a procedure, however, which is not very appealing as a commercial method. Titanium and the alloys available at present are not recommended for continuous service above 1000 F. Attempts to develop alloys suitable for elevated temperature service continue for the metal has a number of features which make it attractive for such service. If suitable alloys cannot be found, it may be possible to develop methods to protect the surface.

The fatigue strengths of titanium and its commercial alloys compare favorably with those of the steels when determined on standard polished specimens. As a matter of fact, the ratios of fatigue strength to tensile strength for the titanium alloys appear to be somewhat higher than those for the steels.

However, there is considerable difference of opinion on the effects of notches. Some authorities are of the opinion that titanium and its alloys are quite notch-sensitive, while others maintain that the notch-sensitivity is similar to that of the steels. There is not sufficient information available to make a definite statement on this problem at present. However, it should be recalled that most of the work has been done on material produced in the rather early stages of commercial production. It is possible that notch-sensitivity will be reduced when the uniformity of the alloys has been improved. As a matter of fact, one commercial alloy has shown considerable improvement in this property during the past few months. Until such time as this point has been definitely decided, one way or the other, the engineer dealing with dynamically stressed parts should consider the possibility of notch-sensitivity in designing for titanium alloys.

On the other hand, for applications involving cyclic stresses in corrosive environments such as sea water, it seems to be generally agreed that titanium and its alloys have excellent properties. Endurance tests made on commercial titanium have indicated that there is very little difference in fatigue strength between samples tested in air and those tested in salt-water.

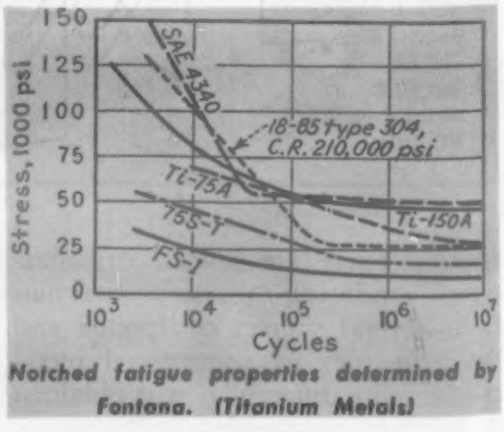
Titanium has excellent corrosion resistance in many environments, particularly to chlorides and under oxidizing conditions. It is resistant to oxidizing acids such as nitric and aqua regia, to dilute sulfuric and hydrochloric, and to most organic acids at room temperature. It is attacked by concentrations over 5% of hydrochloric acid, the rate increasing with the temperature. The metal



Hot hardness values of forged titanium alloys. (Mallory-Sharon)

is not resistant to hydrofluoric and phosphoric acids at room temperature. It is resistant to dilute alkalies but is attacked by moderately concentrated solutions. In resistance to chlorides, titanium is outstanding. It is particularly immune to attack by sea water and is not pitted by stagnation in crevices, under moist salt crystals, and under fouling growths. It resists boiling dilute solutions of many of the chlorides also. Titanium appears to be immune to stress-corrosion cracking in hot 10% sodium hydroxide and boiling saturated magnesium chloride, solutions which attack some of the alloy steels severely.

Recent solution potential studies indicate that titanium is cathodic to most of the metals used in aircraft construction. Thus, titanium will not corrode in normal and marine atmospheres even when coupled to other metals. These results are similar to those obtained previously in sea water tests. The investigation indicated also that nascent hydrogen and oxygen do not dissolve in titanium at room temperature. Since there are so many factors which affect the corrosion rates, the remarks made above should be used only as indicative of the corrosion resistance of titanium. Before selecting the metal for applications involving corrosion, tests should be made under service conditions.



Notched fatigue properties determined by Fontana. (Titanium Metals)

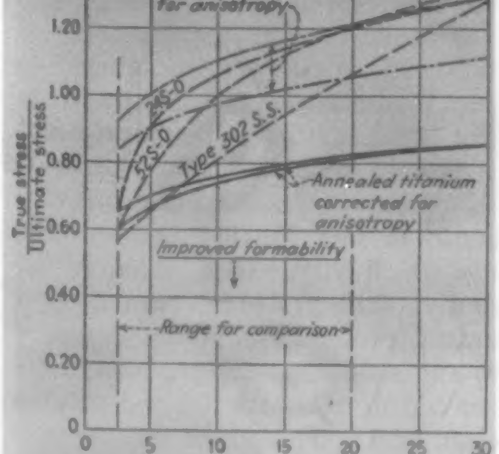
Working and Forming

Most of the information on the forming of titanium sheet is the result of work done in the aircraft industry. Although there are naturally some differences of opinion on the ease of fabrication, such information as has been released indicates that the normal troubles to be expected in working with a new material are gradually being overcome. One of the major difficulties, which will be overcome only with the perfection of better methods of melting and casting, is lack of uniformity of the material. At present, one organization after another notes that variations occur from ingot to ingot. Variations from sheet to sheet plagued the fabricators until recently. However, considerable improvement has occurred during the past few months. Because of these variations, fabrication procedures have been selected to allow for lack of uniformity which means, in many cases, the use of less drastic procedures than will be possible when more uniform material is generally available.

Commerical titanium sheet can be formed by bending, spinning, stretch forming, drawing, and similar operations. The formability of annealed sheet has been compared to that of ¼ to ½ hard 18:8 stainless steel.

Annealed sheet up to 0.095 in. thick can be bent cold 180 deg parallel to the rolling direction on a radius of ½T and perpendicular to the rolling direction on a radius of ¾T. In the aircraft industry, however, bends of 3 to 5T have been used to compensate for property variations from sheet to sheet, grain direction, and surface imperfections in the sheets, the quality of which has not been equal to that of the stainless steels and aluminum alloys. This condition will undoubtedly be improved as larger and more uniform ingots are produced and more experience is gained in the rolling of titanium.

Exploded view of a titanium hydraulic fitting produced by the Crawford Fitting Co. With this type of fitting, flaring of the tube is not required.



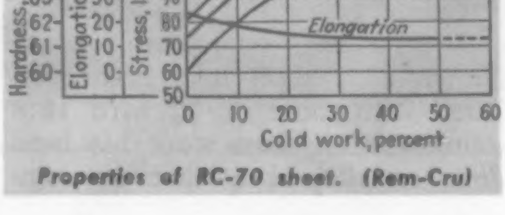
Deep drawing formability criterion of commercial titanium sheet compared with other materials. (W. Schroeder, Lockheed Aircraft)

Bending of ½ hard sheet requires radii of the order of 5T although, here again, several aircraft organizations double this figure for room temperature bending, reducing the figure to 5T by heating the material to 500 to 600 F. Spring back characteristics of material formed at room temperature are similar to those of the stainless steels.

Stretch forming is somewhat more difficult than similar forming of stainless steel, but development toward improving the operation is being pushed by several organizations.

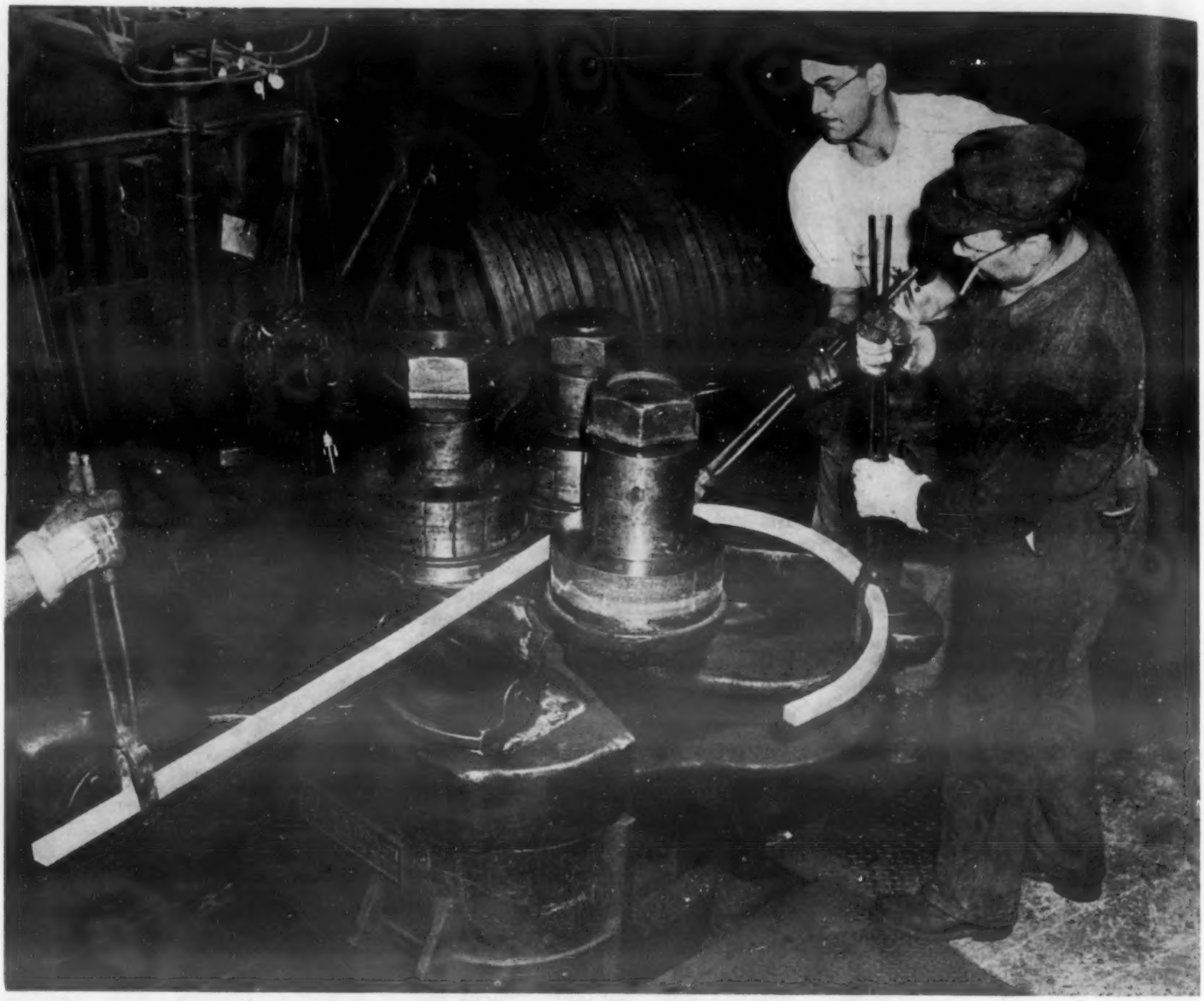
The present status of the deep-drawing of titanium can be judged from the following comments. One organization reports that annealed commercially-pure titanium sheet has deep drawing properties comparable to 24S-O aluminum but somewhat inferior to those of the annealed stainless steels. Another states that the permissible reduction of area in drawing round parts is equal or superior to that of type 302 stainless steel, a material which is credited with excellent drawability. It has been stated by a producer of deep-drawn shapes that any part which can be deep-drawn using mild steel can be duplicated with annealed titanium.

Titanium alloy forgings produced at the Naval Gun Factory. After forging in closed dies at 1850 F, they were trimmed, given a light finishing blow, and wet blasted.



Properties of RC-70 sheet. (Rem-Cru)

As should be expected, certain modifications in the process are necessary. Press speeds should be lower than those used for steel and more frequent annealing is required. In one investigation, annealed sheet showed a tendency to crack in areas where bending occurred. However, when ample punch and draw radii were used very good deep drawing properties were found. Based on this investigation, a draw radius of 8T was recommended. Because of the galling characteristics of titanium, high draw pressures result, particularly when drawing large blanks. Pick-up and galling are serious problems, and the draw-ring may require cleaning after producing two or three



Hot forming a titanium ring prior to welding. (American Welding)

parts to avoid failures caused by sticking.

Development of suitable lubricants is a continuing investigation. Sulfurized and chloridized polar lubricants appear to be favored at the moment while selective surface oxidation, phosphate coating or copper plating to reduce seizing have also been suggested. A proprietary method of coating the surface with solid film lubricants, based on graphite and resins, is said to prevent galling and seizing of titanium and its alloys.

Dimpling of sheet for flush-head rivets requires high pressure. In some sizes the operation can be accomplished successfully at room temperature. For large diameter rivets or for work-hardened material, it is necessary to heat the sheet before dimpling to prevent cracking. Temperatures in the range 500 to 600 F are satisfactory.

Commercially pure titanium has been cold headed to form rivets and other fasteners using regular production equipment. Some organizations suggest heating the rivets for driving to obtain satisfactory heading but cold-driving operations are quite feasible although special rivet-sets are recommended. Monel rivets are being employed by at least one aircraft manufacturer instead of titanium rivets. Much of the work on cold heading is still on an experimental basis, and it has been reported by one firm specializing in fasteners that not too much success has been achieved in producing screws, nuts and bolts. Others indicate that the difficulties can be overcome by roll-threading instead of thread-cutting.

The forming characteristics of titanium alloy sheet have been compared with those of ¾ hard 18:8 stainless steel. Less work has been done on alloy sheet than on commercial titanium, but indications are that such forming can be done most satisfactorily by following the procedures used in forming magnesium and the stronger aluminum alloys, such as 75S-T—that is, by heating the sheet for forming.

Procedures for the forming of RC-130A sheet were developed by one organization and certain tentative methods have been proposed. It should be noted that this work was done last year and that improvements in sheet quality and uniformity which have been achieved recently will probably permit more drastic procedures. Shears equipped to cut stainless steel are satisfactory for cutting this material and produce clean edges. The power requirements are similar to those required for ¼ hard stainless.

Power brake forming at room temperature requires radii of 3T for successful bending. Spring-back causes

considerable trouble, which can be reduced by using rubber female dies. Forming at 200 to 400 F after soaking the alloy at 550 to 600 F produces good bends at high rates using radii of 2T and with only 40% of the spring back resulting when similar bends are made at room temperature.

For successful forming of RC-130A using the Guerin process, pressures of 2000 to 5000 psi at 400 to 450 F are necessary. Spring back is directly related to the forming temperature and pressure.

For stretch forming under controlled conditions, elongations approaching 60% of those obtained on a 2-in. gage length in the tension test can be obtained. The alloy has a tendency to neck locally during longitudinal stretching, a condition which can be minimized by interrupted straining.

Dimpling for 5/8-in. dia rivets was done without cracking at room temperature on 0.030-in. sheet, but special punches and dies were required, and high pressures were necessary for successful results.

Preliminary mechanical joggling tests indicate that the material can withstand fairly severe cold working. The joggling characteristics of the alloy have been compared with those of 1/4 hard stainless steel.

Forging

The forging of titanium and its commercial alloys is accomplished quite readily by conventional procedures, but certain variations are required from alloy to alloy and the manufacturer should be consulted for specific recommendations. These materials flow easily, readily fill the dies, and give good sharp impressions. On a weight basis, about 30% more force is required than would be required for steel, and it has been suggested that dies be more massive than those used for steel. Flash can be removed in regular trimming dies without danger of tearing.

It has been recommended by some organizations that the upper limit of temperature for forging be 1800 F, because the rate of penetration of oxygen and nitrogen into the metal becomes very rapid at higher temperatures and the resulting scaling and surface hardening can become a serious problem. Others prefer to set the upper limit at 1700 F. Forging of most alloys should be continued until the temperature drops to 1300 to 1400 F, if the equipment is sufficiently rugged, for the mechanical properties of the part are improved by this procedure. Reductions should be light to prevent cracking, and it has been suggested that the initial break-down could be done profitably in a press rather than

Checking the temperature after hot forming a titanium section at Douglas Aircraft. Heating the piece virtually eliminated breakage in bending operations.

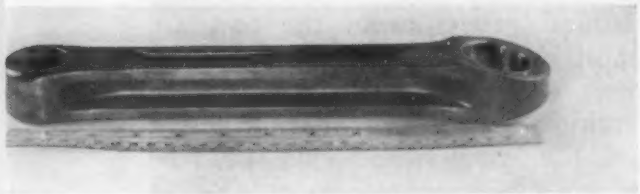
under the hammer, although die-life might be a factor in such a procedure. This suggestion is based on the fact that titanium resists rapid deformation to a greater degree than slow deformation. After forging, a number of organizations anneal the piece at 1200 to 1300 F.

Regular heating furnaces can be used, but the floor should be free from iron scale or the titanium should rest on clean bricks. It has been reported in several instances that titanium bars have reacted with mill scale, the reaction being exothermic and resulting in the complete oxidation of the bar.

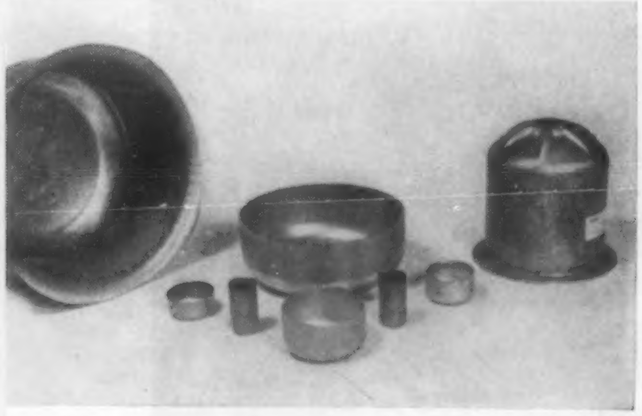
To reduce scale formation, the preferred practice is to soak the piece at 1200 to 1300 F and raise the temperature rapidly to 1700 to 1800 F, holding at the latter temperature for the minimum possible time. No special atmosphere is required, although excessive water vapor atmosphere should be avoided.

Small reductions can be made by cold swaging, but care is required in this operation. Excessive working at room temperature can result in the cracking of the part. Swaging can be performed quite readily if the bars are heated to 400 to 500 F.

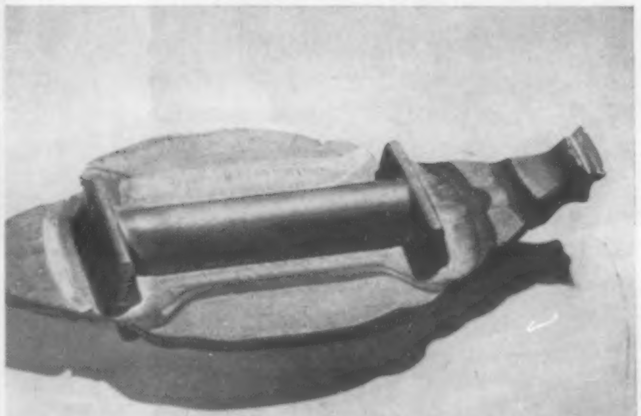
Machining and Grinding



Titanium alloy articulated connecting rod forged by Wright Aeronautical.



Deep drawn titanium parts. Proper lubrication is essential to prevent galling or scoring. (Worcester Pressed Steel Co.)



Drop forged titanium alloy conveyor belt link. The forging of titanium alloys can be done by conventional methods. These materials flow easily, readily fill the die, and give good sharp impressions. (Mallory-Sharon)

Machining

Although it has been stated frequently that the machining of titanium is difficult because of work hardening, recent work has indicated that such is not the case, but instead, the tool materials actually alloy with the titanium and particles of the tool are washed away. Improvement can be expected if metal to metal contact is reduced by adequate lubrication.

Titanium resembles the stainless steels in the type of chip formed during machining operations, but there is considerable difference of opinion concerning the relative machinability of these materials. Some engineers state that titanium is more difficult to machine than the stainless steels, while others maintain that titanium is more readily machinable and the ease of machining increases with the purity of the metal. Some of these differences in opinion may be the result of careless nomenclature. The term titanium has been used loosely to include the commercial metal and also the alloys, materials which have quite different properties and can be expected to have different machinability ratings. One estimate of relative machinability rates titanium and titanium alloys in the 15 to 20% range and 18:8 stainless at 25% based on a rating of 100% for B1112 steel. Recent work in the aircraft industry has indicated, however, that the alloys 150A and MST3Al-5Cr should be compared in relative machinability with the high temperature jet engine alloys rather than with the stainless steels.

In general, tool designs which have been used successfully in machining the austenitic stainless steels are satisfactory for machining titanium and its alloys. For roughing cuts, speeds of 45 to 60 surface ft per min with minimum feeds of 0.030 in. per revolution and a depth of cut about double the feed have been found to work satisfactorily. For finishing cuts, the speed is increased to about 70 sfm and a minimum feed of 0.015 in. per revolution with a depth of cut equal to the feed can be used. Although slow-speed machining is usually recommended, another successful procedure currently being employed for commercial titanium uses speeds of 300 sfm with a 0.012-in. feed for turning operations. In machining these materials, the tool should be worked as heavily as possible, a sharp tool is essential, and the tool should not be permitted to dwell, for burnishing will occur, making further machining difficult.

One of the major problems in machining these materials is the tendency of titanium to weld to the cutting tool with resulting galling and seizing. Successful machining requires either the use of a suitable lubricant, which should have the highest possible lubricity, or adequate cooling of the work. There is considerable disagreement on the exact function of the cutting fluid, some authorities believing that it acts merely as a coolant.

Although some organizations are using the same cutting fluids they use for the machining of other metals in their shops, improved lubricants are available which should facilitate the machining operation. Cutting oils containing sulfur additives have been effective in reducing welding under severe cutting conditions, while cutting oils to which chlori-

Boeing engineers examine welded titanium tubing. The unalloyed material can be readily welded by several processes.

nated solvents such as carbon tetrachloride have been added are more effective at low speeds and lighter cuts. Cutting fluids have been developed for the machining of titanium and its alloys which contain active sulfur, active chlorine in a nontoxic form, and polar type fatty additives combined with a mineral oil of the correct viscosity for the operation to be performed.

A recent development in which small high-speed jets of oil are directed at the point of contact between the work and the cutting edge has been reported to enable rapid cutting of titanium in single-point tool operations.

Another development which shows some promise in improving the machinability is a procedure in which liquid carbon dioxide is released at the cutting edge of the tool. Cutting speeds of more than 300 sfm have been employed when using this method, which has been applied to the lathe cutting, milling, drilling and broaching of titanium.

In all cutting operations it is necessary to observe the rule that the feed must not be disengaged while the tool is moving in contact with the work. This rule has been applied particularly to drilling and tapping, which are generally considered to be difficult operations. Pilot holes cannot be used and the enlarging of holes should be avoided. The most promising procedure developed is eccentric drilling using high-cobalt drills with notched lips. Slow speeds with feeds double those usually employed in drilling the stainless steels are desirable. However, there is disagreement here also since some organizations have indicated that no particular difficulty was experienced in these operations. The hard chromium plating of high-speed steel drills, taps and reamers is reported to reduce chip welding and subsequent galling, also. The cutting of external threads should be done by milling or chasing in a lathe, if possible. If dies are used, complete welding of the die to the work may occur.

The sawing of titanium and its alloys is a difficult operation, particularly in heavy sections. Heavy positive cuts are desirable. Satisfactory results have been obtained recently with a number of machine saws, but the work was flooded with a soluble oil and water coolant during the operation to avoid heat cracking. For hack-sawing, current recommendations call for an extremely coarse saw (two to four teeth per in.) with slow speeds and heavy feeds. Fine-toothed saws and conventional feeds are reported to be unsatisfactory for sawing titanium. On the other hand, in sawing the alloys, one organization reports that the best results with RC-130A are obtained with a 32 pitch wavy set blade operating at speeds less than 100 sfm with feeds of 3 to 5 in. per min. Blade widths of ½ in. are satisfactory for sawing sheet, but unsupported flanges require wider blades.

Wet abrasive cut-off wheels are recommended by some organizations as the best method of cutting titanium. For successful cutting, the work should be rotated in order that the wheel can cut toward the center and is not required to cut entirely through the piece. Oscillating the wheel is

Tentative Recommendations for the Surface Grinding* of Titanium and Its Alloys

Wheel Material	Alumina
Designation	32A60-L8VBE or 32A60-K8VBE
Wheel Speed	2000–3000 sfm
Table Speed	400–500 in. per min
Downfeed	0.001 in. or less
Grinding Condition	Wet
~~Application~~	~~Commercial titanium, Ti-150A, RC-130B~~

* *Low wheel speeds are applicable to vitrified wheels in other precision grinding operations.*

Courtesy of Norton Co.

also helpful. It has been reported that 7-in. dia bars have been cut by this procedure in 10 min while ½-in. bars have been cut in a few seconds.

Friction sawing, diamond sawing and flame cutting have been used also. The latter is a rapid method of cutting these materials, but the resulting surfaces are hard and introduce difficulties in subsequent machining operations.

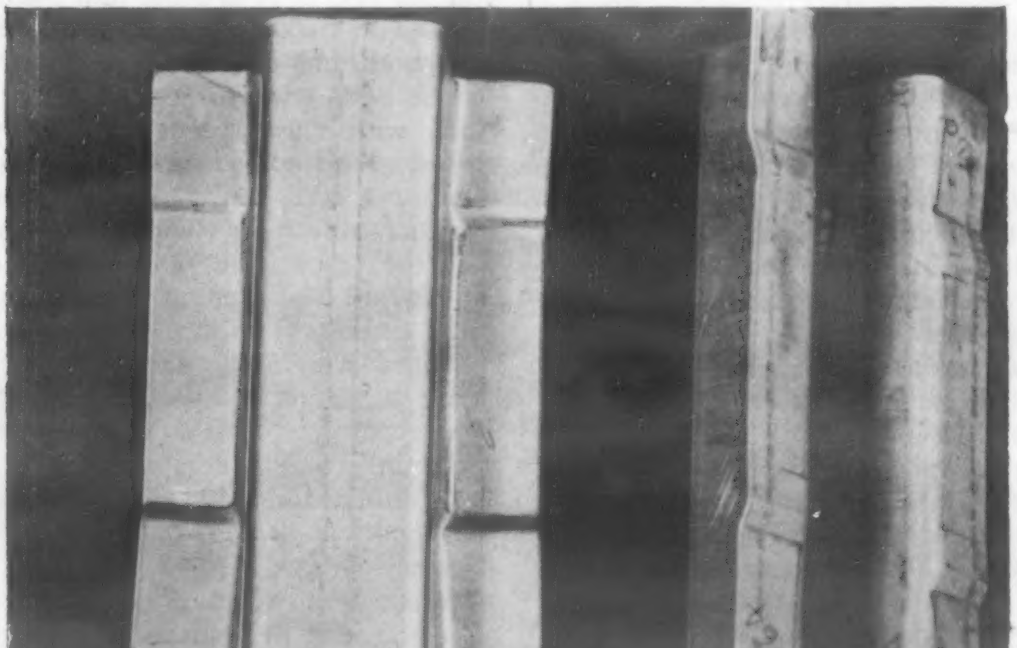
Grinding

Because of the extremely high rate of wear of the wheel, titanium and its alloys are difficult to grind. Aluminum oxide wheels are listed at present as the best for the purpose, although soft-bonded silicon carbide is preferred by at least one organization. Since titanium dust, like that of the other light metals, is explosive, wet grinding procedures should be employed if possible. Wet grinding also assists in preventing thermal cracking caused by localized overheating, which can result from the very low thermal conductivity of titanium. Several organizations recommend post-grinding annealing at 1200 to 1300 F to prevent cracking, especially for the high-strength alloys. An alternate method which has been proposed is hot-grinding in the range 500 to 600 F. However, these methods apply to snagging rather than to precision grinding.

Recent work indicates that when the most suitable grinding fluids are used for surface grinding the commercial titanium alloys at slow wheel speeds, in the range of 2000 to 3000 sfm, the rate of wheel wear is similar to that for hardened high-speed steels ground in the usual manner. It has been suggested, therefore, that the tolerances obtainable in grinding titanium alloys under the best known conditions should be comparable to those obtained in grinding similar parts made of high-speed steel.

Current recommendations for surface grinding the titanium alloys call for the use of alumina wheels and slow wheel speeds of 2000 to 3000 sfm. Slow speed is said to be the key to successful grinding by several organizations. This development of grinding procedures is now past the preliminary stages and the operation is less difficult than it was only a few months ago. The accompanying table indicates a procedure which which has given good results. Since considerable grinding is required in mill processing while fabricated articles may require finish grinding, revised recommendations can be expected to be released as soon as improved methods are devised. At present, grinding operations are being done successfully but at relatively high abrasive costs.

Cleaning and Finishing



Joggled titanium alloy hat section made by Chance Vought for the Navy Bureau of Aeronautics on an experimental program. Tests showed the alloy could withstand reasonably severe cold working if material was completely supported in region being worked.

The descaling and cleaning of titanium and its alloys can be accomplished by chemical or mechanical means. Light discoloration can be removed by immersion of the part in a pickling solution composed of 2% hydrofluoric and 10% nitric acid by volume. However, this solution will not remove the scale formed when titanium is annealed in air. For this purpose, a number of organizations are using the Virgo or caustic bath, operated at about 800 to 850 F, particularly in the treatment of sheet and strip. Others are descaling with sodium hydride. Following either of these treatments, the material is quenched in water and dipped briefly into a hydrofluoric-nitric acid solution to brighten the surface.

There is some difference of opinion on the possibility of the embrittlement of the material as a result of this type of descaling. On the

Flash butt welding a titanium ring at the American Welding & Manufacturing Co. Methods for titanium resemble those for aluminum more closely than those for steels.

one hand, it has been stated that there is no danger of embrittlement using the Virgo or commercial sodium hydride procedures if normal conditions are employed, but there is definite possibility of embrittlement if caustic soda alone is used because of the high temperature required for satisfactory removal of the scale. On the other hand, it has been reported that sodium hydride descaling can cause some embrittlement, particularly of thin sheet. A pickling procedure using a hydrochloric-hydrofluoric mixture at room temperature is a recent development which shows promise. No previous caustic treatment is necessary. Surface staining, resulting from fingerprints or oil marks, can be removed using the usual commercial detergents.

Titanium scale can be removed mechanically by grit or vapor blasting, if a matte finish is permissible. This procedure is usually employed for heavy sections, such as bars, rods, plates or forgings. It is sometimes followed by a chemical treatment to insure the complete removal of the scale.

The electroplating of titanium to produce wear resistance surfaces is still under development. Conventional methods of chromium plating produce non-adherent coatings. Methods of delivering the titanium to the plating bath with an oxide-free surface appear to be necessary to obtain suitable adhesion. Several promising procedures for accomplishing this objective have been devised but none is commercial at the present time. Other plating procedures for the production of wear resistant or decorative coatings have not been reported, although the copper-plating of titanium to reduce galling during working is a commercial operation.

Titanium can be anodized by treatment in a chromic or sulfuric acid bath. The surface resulting from this treatment can be dyed and sealed by procedures similar to those used for aluminum.

Joining

Titanium and its alloys can be welded to themselves by resistance or inert-gas-shielded arc methods. However, welding procedures for joining these materials to other constructional metals are still in the development stage, although recently one organization has reported that successful joints were made between commercial titanium and an aluminum alloy. The tendency of titanium to absorb oxygen and nitrogen when heated to high temperatures complicates the welding procedure, since these gases embrittle the material. The response of the alloys to heat treatment is discussed later. Brazing to dissimilar metals has been reported but methods for soft soldering have not been developed.

For the production of satisfactory welds, the oxide scale formed during annealing must be removed by methods such as those discussed previously. Spot welding does not seem to be affected by the oxide coating which forms on titanium at room temperature, but for flash-butt welding the contact areas must be cleaned.

The spot-welding of commercial titanium sheet offers no particular problem, and satisfactory welds can be made over a wide range of conditions. The weld time in cycles is about the same as that required for low carbon steel of the same thickness, but the welding current is approximately 50% greater. From 25 to 50% more pressure on the elec-

Ryan engineers check the dimensions of a Piasecki shroud section fabricated from titanium.

Hot forging a 1000-lb titanium ingot at Rem-Cru.

trode tips is desirable also. Excessive penetration is characteristic of titanium spot welds and, in the tests run by one organization, no weld was made with less than 80% penetration. Since the welds are less ductile than the base metal, conditions should be adjusted, by trial, to limit the penetration. However, one aircraft company reports that titanium readily meets the weld quality requirements for penetration, shear strength uniformity and soundness established by this organization for stainless steel sheet.

The spot welding of titanium alloy sheet is still in the development stages. Some experimental work has indicated that single-phase alloys can be welded more satisfactorily than two-phase alloys. Unfortunately, all of the alloys available commercially at present are two-phase materials.

One organization reported that attempts to join titanium and type 347 stainless steel by spot welding were unsuccessful. The weld nugget formed was so brittle that it was difficult to section the weld for examination. Other reports of similar difficulties indicate that the spot welding of titanium and its alloys to dissimilar metals will require a great deal more study before satisfactory results are obtainable.

Flash butt welding techniques for titanium and its alloys resemble those for aluminum alloys more nearly than those for steel. A relatively short flashing cycle is desirable, during which the butted ends are heated to fusion in the arc. A rapid forging cycle with the ends being upset and joined completes the weld. Upset pressures are higher and current densities are lower for titanium than for aluminum, although it has been reported that standard total losses, upset flash and voltage settings can be used.

Care is necessary at the beginning of flashing to prevent the formation of joints, prematurely. For heavy sections, this is achieved by pointing the ends of the bars to concentrate the current when the arc is struck. Titanium tubing has been joined satisfactorily by the process also. In addition to commercial titanium, the alloys RC-130B and Ti-150A are being joined commercially by flash butt welding. The mechanical properties of the welds in these alloys are said to be equal to those of the parent metal. It has been reported that commercial titanium has been joined to type 61S aluminum by this process and, on testing, the failures occurred in the aluminum alloy.

Commercial titanium can be joined successfully using the inert-gas-shielded arc process. For this operation, however, all parts of the assembly which are heated above 1200 F must be shielded from contact with the air, either with an inert gas or by backing with a metal such as copper. The latter expedient has been used in welding thin sheet, for its assists in maintaining alignment. Uniformity is best if direct current straight polarity is used instead of alternating current, but penetration and strength are equally good with either a.c. or d.c. Annealed welds are less ductile than the parent metal if annealing is done in air. However, one organization reports that welds which are vacuum-

annealed after inert-arc welding with tungsten electrodes are practically as ductile as the parent metal. Filler rods of materials other than titanium are not satisfactory because extremely brittle welds result. Welding of the alloy grades by the inert-arc process has not been so successful. Although the joints have been satisfactory, the ductility is very low and no improvement has resulted from heat treatment.

The brazing of commercial titanium to itself and to other materials is still in the development stage. Using a proprietary flux developed recently, good results were obtained with silver brazing alloys by furnace, oxyacetylene torch and salt bath procedures. However, the alloy layer formed between the silver solder and the titanium was very hard and brittle. Failures on testing single lap joints occurred in this layer.

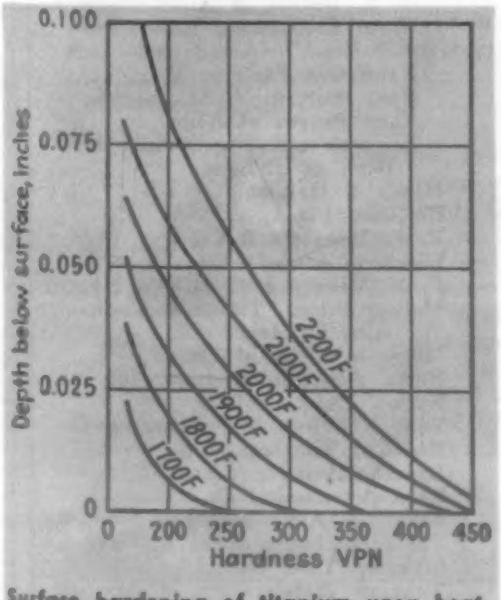
Brazing with aluminum alloys has been investigated also. Preliminary work indicated that satisfactory joints could be made. The alloy layer was softer than titanium, and it would appear that the strength of the joints would depend on that of the aluminum alloy rather than on that of the intermediate zone.

It has been reported that titanium can be brazed to dissimilar metals using copper-titanium as the brazing alloy and heating the assembly in a vacuum. Silver-brazing of titanium to cold-rolled steel in an inert atmosphere has been reported also. Another organization stated that vacuum-tight joints had been produced between titanium and copper and titanium and monel by silver brazing. However, the assemblies, which were prepared for use in x-ray tubes, either cracked or developed leaks during operation of the tubes. Thus, it would appear that the brazing of titanium is still far from a commercial operation.

Heat Treatment

The crystal structure of titanium changes at 1625 F from hexagonal close-packed alpha (the room temperature modification) to body-centered cubic beta. Slight hardening effects resulting from this structural change have been reported for quenched titanium but have no practical significance. On the other hand, some of the alloys can be hardened.

Commercial titanium can be annealed satisfactorily by heating to 1200 to 1300 F for periods of time depending on the thickness. In general, the alloys can be annealed in the same range. Strain hardening can be removed by heating in this temperature range for 10 to 15 min. There is a difference of opinion on the effect of the atmosphere during annealing. Some investigators consider that annealing in air is satisfactory for heavy sections, but there is definite danger of embrittlement if thin sheet, tubing and wire are so annealed. For such materials they suggest annealing in an inert atmosphere. Others believe that the relatively short time required to anneal thin sheet at 1200 F makes it possible to anneal such sheet in air without danger of embrittlement. All agree that holding the material for long periods in this temperature range or annealing at higher temperatures in air can result in a heavy scale formation and the possibility of embrittling the material. Titanium can be stress relief annealed at temperatures in the range 600 to 800 F.



Surface hardening of titanium upon heating in air for 1 hr at the temperature indicated. (Titanium Metals)

The titanium-base alloys which have been produced commercially thus far contain additions of iron, chromium, vanadium, molybdenum or manganese, each of which stabilizes the beta form so that some of this phase is retained to or below room temperature. Thus, these alloys are mixtures of alpha and beta titanium. They are modified but not changed basically by the addition of elements which strengthen the alpha phase, including aluminum, nitrogen, oxygen and carbon. The benefits obtained from the alpha-strengtheners are not so apparent at room temperature as at elevated temperatures. Alloys which contain alpha-strengthening elements retain their strength to higher temperatures than those which do not contain these elements.

The commercial alloys currently available can be modified by heat treatment, and several organizations are actively engaged in developing suitable methods. Up to the present time, only limited procedures have been revealed. Among those suggested for obtaining certain desirable properties are: (1) Air cool from 1400 F for the best combination of

Forging heated titanium in a closed-impression die on an 8000-lb steam hammer at Steel Improvement & Forge Co.

Stretch forming of jet plane after-burner shields of titanium and other materials at the Cyril-Bath Co.

yield and tensile strength; (2) quench from 1600 F and temper at 1300 F for retention of elongation with slightly increased strength; (3) air cool from 1800 F for highest yield and yield/tensile ratio.

Surface hardening by absorption of oxygen and nitrogen occurs when titanium-base materials are heated at high temperatures in air. Experimental values are shown in an accompanying graph. These results indicate that the selective hardening of the surface by procedures analogous to those used for steel is possible. Thus, it is not surprising that a patent has been issued for the surface hardening of titanium by treatment with molten cyanide. It is claimed that by the use of substantially oxygen-free cyanide, a cyanonitride coating is formed, which is only a few ten-thousandths of an inch thick but is extremely hard and corrosion resistant. On the other hand, if commercial cyanide is used, much thicker coatings can be obtained but they are the result of the absorption of oxygen and nitrogen. The coatings developed by the two procedures are said to be quite different in properties.

Commercial titanium welding elbow produced by Tube Turns, Inc. Because of its excellent corrosion resistance, titanium will be widely used in the process industries.

Applications

In sheet form, unalloyed titanium is now being employed commercially by one aircraft manufacturer for shrouds, cowles, redundant bulkheads and fire-walls. The shrouds, which shield the high-temperature exhaust system of the Piasecki helicopter, have been constructed of titanium. The part must withstand temperatures of 400 to 500 F, and this appears to be an ideal application for the metal. Considerable interest is evident in the use of commercial titanium for aerodynamic surfaces of supersonic aircraft. At the higher speeds, the temperatures resulting from aerodynamic heating approach values which are too high for aluminum alloys, and higher melting materials such as titanium are necessary. Titanium alloy sheet is now under consideration for the longerons or rib-sections of the fuselage.

Titanium alloy forgings are under development for jet engine parts such as compressor disks, blades, stator vanes and spacer rings, while a number of other forged shapes have been made on an experimental basis.

In addition to titanium rivets, consideration is being given to the use of mechanical fittings of titanium in aircraft to replace riveting. Such fittings could also replace the stainless steels bolts now being used. It has been stated that, if all stainless steel bolts were replaced by titanium alloy bolts in one type of aircraft, there would be a weight saving of 500 lb.

Hydraulic lines and fittings of commercial titanium are also under consideration for aircraft service. As it is difficult to flare the ends of titanium tubing under field conditions, fittings have been devised which do not require the flaring of the tube.

The Defense Dept. is interested in the development of titanium alloy components for air-borne and man-borne equipment because of the saving of weight which would be possible by the replacement of steel with titanium.

Commercial titanium is in use on a limited scale for corrosion resistant equipment in the chemical field. Currently, large installations are under construction for handling 22% sulfuric acid at high pressures and temperatures and for handling concentrated ferrous chloride solutions. A pharmaceutical producer has incorporated titanium tubing into certain process equipment. Because of its excellent corrosion properties, titanium will probably find wide application in the chemical field when larger quantities are available for testing and installation.

The exceptional resistance of the metal to salt water corrosion assures it a field in marine applications when the price has been reduced. Even at present prices, the Navy is definitely interested in applying the metal to certain small parts in which a critical corrosion problem exists.

Most of these applications are in the development stage at the present time. Many other uses have been suggested, most of which will be commercial only when the price of the metal has fallen to a more competitive figure.

Acknowledgments

The author wishes to acknowledge with sincere appreciation the help obtained in the preparation of this manual from personnel and publications of the following organizations:

Allison Div.
American Welding & Manufacturing Co.
American Society for Testing Materials
Battelle Memorial Institute
Boeing Airplane Co.
Carborundum Co.
Chance Vought Aircraft Div.
Chicago Development Corp.
Cincinnati Milling Machine Co.
Crane Co.
Crawford Fitting Co.
Curtis-Wright Corp.
Cyril Bath Co.
Douglas Aircraft Co., Inc.
E. I. du Pont de Nemours & Co., Inc.
East Coast Aeronautics, Inc.
Electro-film Corp.
Eureka X-ray Tube Corp.
Fairchild Aircraft Div.
Foote Mineral Co.
General Plate Div.
Government Agencies—
U. S. Bureau of Mines
Naval Engineering Experiment Station
Naval Gun Factory
Navy Bureau of Aeronautics
Navy Bureau of Ships
Research and Development Board Dept. of Defense
Handy & Harman
Horizons, Inc.
E. F. Houghton & Co.
Lockheed Aircraft Corp.
P. R. Mallory & Co., Inc.
Mallory-Sharon Titanium Corp.
The Glen L. Martin Co.
Monsanto Chemical Co.
North American Aviation, Inc.
Norton Co.
Reed & Prince Manufacturing Co.
Rem-Cru Titanium, Inc.
Republic Aviation Corp.
Ryan Aeronautical Co.
Society of Automotive Engineers, Inc.
The Steel Improvement & Forge Co.
Superior Tube Co.
Titanium Metals Corp. of America
Tube Turns, Inc.
Westinghouse Electric Corp.
Worcester Pressed Steel Co.
Wright Aeronautical Div.

Materials & Methods

Materials Engineering File Facts

NUMBER 227
May, 1952

Materials Data Sheet

The Precious Metals

The metals gold, silver, platinum, palladium, rhodium, ruthenium, osmium and iridium are known as the precious metals. Their uses in jewelry and the arts have obscured the fact that considerable quantities are used also in engineering applications. Among such applications are corrosion resisting equipment, bearings, solders, electrical contacts and catalysts.

	Gold	Silver	Platinum	Palladium
COMPOSITION, %	See footnote	See footnote	See footnote	See footnote
PHYSICAL PROPERTIES				
Density, Lb/Cu In.	0.698	0.379	0.775	0.434
Melting Point, F	1945	1761	3224	2829
Thermal Cond, Btu/Hr/Sq Ft/Ft/F, @ 212 F	172	242	42	41
Coeff of Exp per F: 32–212 F	7.9×10^{-6}	10.9×10^{-6}	4.9×10^{-6}	6.5×10^{-6} (a)
Spec Ht, Btu/Lb/F:	0.031	0.056	0.031	0.058
Elect Res, Microhm-Cm @ 32F	2.35	1.59 (a)	14.9	10.8 (a)
MECHANICAL PROPERTIES				
Mod of Elast in Tension, Psi	12×10^6	11×10^6	21×10^6	17×10^6
Tensile Str, 1000 Psi:				
Annealed	19	22	17–26	30
Cold Worked	32 (b)	54 (c)	34–45	47
As Cast	18	15	..	..
Yield, Str, 1000 Psi:				
Annealed	Nil	8	2–5.5	5
Cold Worked	30	44	27	30
As Cast	..	5	..	..
Elong in 2 In., %:				
Annealed	45	48	30–40	24–40
Cold Worked	4	2.5	2.5–3.5	1.5
As Cast	30	60	..	..
Reduction of Area, %:				
As Cast	..	67	..	..
Hardness, Bhn:				
Annealed	25	25–35	38–52	46
Cold Worked	58	..	97–13	109
As Cast	33	42	..	..
Fatigue Strength (End Limit) 1000 Psi Annealed	4.6 (10^7 cycles)			
THERMAL TREATMENT				
Annealing Temp, F	Not required	400–600	1475–2200	1475
FABRICATING PROPERTIES				
Hot Working Temp Range, F	Any to m.p.	..	1475–2300	1475–2300
Max Red, between Anneals, %	Apparently unlimited	..	99	99
Casting Temp Range, F	2000–2370	2000	3300	3000
Joining	Braze with silver solder, no flux, any flame. Can be resistance welded by any method. Oxyacetylene welded, no flux, any flame.	Braze with silver solder. Can be resistance welded.	Brazed with fine gold or white platinum solder. Hammer welded at 1800 F. Can be resistance or oxyacetylene welded.	Brazed with an oxyacetylene torch using platinum solders. Can be resistance welded.
CORROSION RESISTANCE	Does not oxidize when heated in air. Resistant to alkalies, salts and most acids. Not attacked by oxygen or sulfur. Rapidly attacked by chlorine and bromine.	Does not oxidize when heated in air. Resistant to most dilute mineral acids and alkalies. Attacked rapidly by nitric acid and by hot sulfuric acid. Attacked rapidly by sulfur-bearing gases.	Does not oxidize when heated in air. Resistant to reducing or oxidizing single acids but dissolved by aqua regia.	Oxidizes when heated in air. Resistant to hydrofluoric, acetic and phosphoric acids. Attacked by nitric, sulfuric and hydrochloric acids, bromine and iodine.
AVAILABLE FORMS	Foil, rod, wire, sheet.	Sheet, strip, rod, wire, tubing.	Foil, sheet, wire, tubing.	Sheet, foil, wire, tubing.
USES	Lining of chemical equipment, high-melting solder, alloys for electrical and chemical purposes, jewelry, dentistry.	Electrical contacts, corrosion resisting equipment, bearings, photography; alloying for coinage, brazing applications, jewelry.	Chemical equipment, electrical contacts, catalysts, laboratory equipment, jewelry.	Electrical contacts, industrial catalysts, production of pure hydrogen, jewelry, dental alloys.

(Continued on page 135)

Materials Engineering File Facts

	Rhodium	Ruthenium	Osmium	Iridium
COMPOSITION, %	See footnote	See footnote	See footnote	See footnote
PHYSICAL PROPERTIES				
Density, Lb/Cu In.	0.447	0.441	0.82	0.813
Melting Point, F	3571	4530	4890	4450
Thermal Cond, Btu/Hr/Sq Ft/Ft/F, @ 212 F	50	..	..	34
Coeff of Exp per F: 68 F	4.6×10^{-6}	5.1×10^{-6}	3.6×10^{-6}	3.8×10^{-6}
Spec Ht, Btu/Lb ° F:	0.059	0.057	0.031	0.031
Elect Res, Microhm-Cm @ 68 F	4.51	7.6 (d)	9.5	5.3
MECHANICAL PROPERTIES				
Mod of Elast in Tension, Psi	42×10^6	60×10^6	80×10^6	74×10^6
Tensile Str, 1000 Psi: Annealed	73	..	..	..
Cold Worked	300	..	..	..
Hardness Bhn: Annealed	55–156	..	..	170
Cold Worked	260–390	..	..	350
As Cast	..	220	350	163
FABRICATING PROPERTIES				
Hot Working Temp. Range, F	1900–2000	2700–4300	Not workable	2200–2700
Max Red, between Anneals, %	30–40	..	..	..
Casting Temp, F	3700	4700	5000	4600
Joining	Can be brazed and resistance welded.	Can be brazed and resistance welded.	Can be brazed and resistance welded.	Can be brazed and resistance welded.
CORROSION RESISTANCE	Oxidizes slowly when heated in air. Resistant to most acids, including aqua regia at room temperature.	Oxidizes when heated in air. Unattacked by common acids, including aqua regia up to 212 F. Moderately attacked by solutions of alkaline hypochlorites.	Oxidizes rapidly in air at elevated temperatures. Resistant to common acids at room temperatures but attacked by aqua regia.	Oxidizes slowly when heated in air. Unattacked by common acids, including aqua regia up to 212 F.
AVAILABLE FORMS	..	..	Cast or sintered parts.	Sheet, wire, rod.
USES	Mirrors and electrodeposits for a nontarnishing finish; alloys with platinum and palladium for crucibles, glass-working equipment, catalysts, spinnerets.	Hardener for platinum and palladium.	Alloys used for pen tips, phonograph needles, electrical contacts, instrument pivots.	Extrusion dies for glass; alloys with platinum for electrical contacts, fuse wires, hypodermic needles and jewelry.

FOOTNOTES:

Gold is generally produced in three grades:
Proof gold, 99.99% Au
Refined gold, 99.95%–99.98% Au
" " 99.5% Au, which is acceptable by the U. S. Mint without penalty.

Platinum is produced in four grades:
Type A, 99.99% Pt sometimes called physically pure
Type B, 99.9% Pt sometimes called chemically pure
Type C, 99.5% Pt crucible grade
Type D, 99% Pt commercial platinum

The other metals are usually refined to "the high purity suitable for general use." In some cases this is spectrographically pure.

(a) *68 F.*
(b) *Cold-rolled 60% reduction.*
(c) *Cold-rolled 50% reduction.*
(d) *32 F.*

Prepared with the assistance of the J. M. Ney Co.

New Materials and Equipment

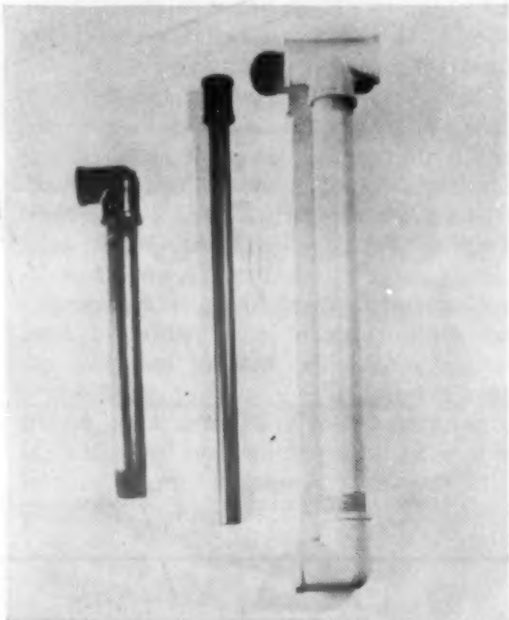
Rubber-Modified Styrenes Feature High Impact Strength

New high-impact resistant plastics developed by *Bakelite Co.* Div. of Union Carbide and Carbon Corp., 122 E. 42nd St., New York 17, are said to give strength to molded parts with thin cross sections and are also extruded in thin tough sheets. Each of the three new formulations of styrene modified with rubber is easy to mold, extrude and machine, and combines excellent electrical properties with the chemical resistance of Bakelite styrene plastic.

The three grades have been designated as QMS-151, QMS-152 and QMS-155. Each grade varies slightly in the degree it includes these useful properties. For example: QMS-155 has the highest impact strength while 151 has the best moldability.

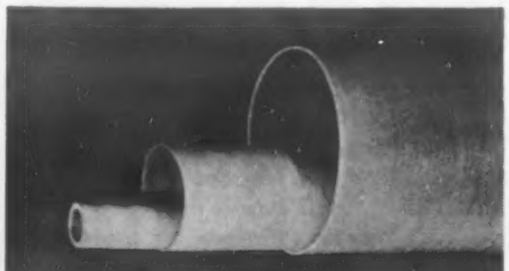
Extruded in sheets about 0.025 in. in thickness, 155 is tough and flexible as it emerges from the extrusion die. Such sheeting is said to resist moisture, tearing and most chemicals. Its remarkable degree of impact resistance is demonstrated in new extruded tubing made of 155 and used in pipe and pipe fittings for farm water supply. Pipe and pipe fittings made of 155 or 152 are also said to resist abrasion, and their aging and weathering characteristics appear similar to those of Bakelite styrene.

For injection molding of large pieces with thin cross sections, a third general-purpose grade of rubber-modified styrene plastic has been used with great success. White refrigerator door liners, for example, are made of QMS-151. All three grades can be injection molded in conventional molding equipment.



The toughest of the new high-impact resistant plastics, QMS-155 can be extruded as black pipe or tubing for use in wells or farm water supply.

Teflon-Impregnated Glass Fiber Successful in Thin Wall Tubing



This Teflon-impregnated glass fiber tubing is suitable for use with virtually every known chemical.

Completion of development work on Teflon-impregnated glass fiber tubing has been announced by *Resistoflex Corp.,* Belleville, N. J. According to the company, this construction provides for the first time the exceptional properties of Teflon in a thin wall tubing or pipe.

The two materials used are said to complement each other, since glass fiber, like Teflon, has exceptional resistance to heat and chemicals. The Teflon makes the tubing suitable for use with virtually every known chemical. The glass fiber reinforces the plastic structure to provide rigidity and strength even in tubing with a wall section of only 0.030 in.

It is expected that the chemical, thermal and electrical properties of the tubing will provide the answer to many problems in chemical processing piping, corrosion-proof conduit, and in other electric and electronic applications.

Welding Rods for Arc and Oxyacetylene Welding of Aluminum

Two new high-purity bare rods for arc or oxyacetylene welding of aluminum have been anounced by *All-State Welding Alloys Co., Inc.,* White Plains, N. Y. The new rods are identified as All-State X-43S Aluminum Rod, meeting government specification QQ-R-566 Type 1 Class FS-RAL-43, and All-State X-2S Aluminum Rod meeting government specification QQ-R-56 Type 1 Class FS-RAL-2.

The former is the cleanest of the high purity 43S aluminum rods and the latter is the cleanest of the high-purity 2S aluminum rods. Their unusual cleanliness is due to the extrusion manufacture to the exact diameter required. Drawing and the possibility of minute surface inclusions of the drawing compound are completely eliminated.

These rods are designed for all work requiring 43S or 2S aluminum wire applied with inert gas, normal arc or torch. Standard diameters include 1/16, 3/32, 1/8, 3/16 and 1/4 in. Standard length is 36 in. and standard package is 50 lb. Both rods are also packaged in coil form. Special lengths can be obtained on order.

The rods are equally applicable with a.c. or d.c. welding equipment and oxyacetylene welding equipment.

New Materials and Equipment continued

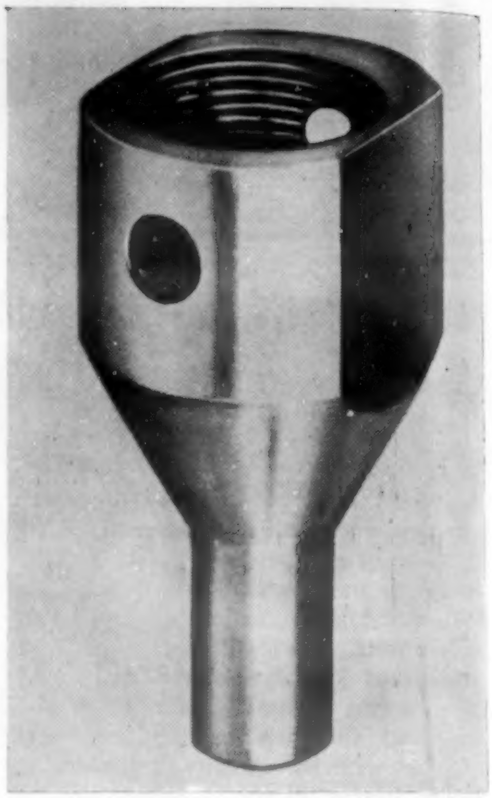
Radiography Sources for Nondestructive Testing

Nineteen cobalt-60 radiography sources ranging in strength from 50 millicuries to 25 curies have been developed by *Tracerlab, Inc.*, 130 High St., Boston. They are now available for use by foundries, heavy metal fabricators and welding shops.

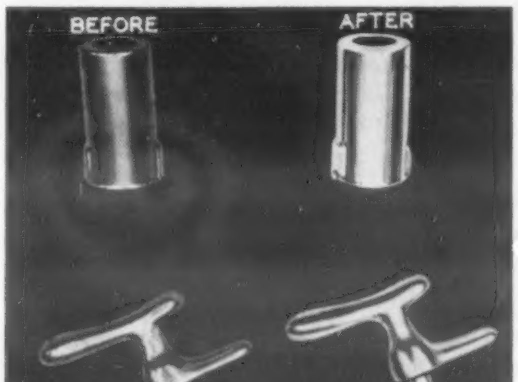
Because of the versatility and low cost, cobalt-60 offers an ideal means for the nondestructive inspection of metal objects for flaws. Gamma rays emitted by cobalt-60 have energies of 1.17 and 1.33 million electron volts, which correspond quite closely to the effective energy of a 2-million-volt x-ray machine. These energies are said to permit examination of steel from ½ to 6 in. without excessive exposure time.

Sources are only 21 mm long by 10 mm wide, allowing them to be placed inside complex castings; are made of ferromagnetic stainless steel; have a large threaded hole to accept a remote handling rod; a small hole to allow handling with string; and have flats machined on each side to prevent rolling.

The absorption coefficient of cobalt-60 gamma rays and thus the exposure time for equivalent sources is very closely comparable to that of radium. Also, cobalt-60 gamma ray energies are said to be sufficiently far above those of maximum scatter to give good radiographic sensitivity without need for complicated blocking and filtering.



This cobalt-60 source can be placed within complex castings and holder is made of ferromagnetic stainless steel.



The brass ferrule and bronze latch at right were burnished for 30 min with Blue Magic Compound No. 11.

Barrel Burnishing Powder for Copper, Brass, Bronze and Alloys

Developed especially to impart excellent color and fine finish to copper, brass, bronze, and copper alloy stampings, castings and other parts that can be barrel tumbled, the new burnishing compound offered by *Blue Magic Chemical Specialties Co.*, 2135 Margaret St., Philadelphia 24, also is said to work very well with certain die casting materials, including slush metals.

The compound is a free-flowing powder, light in color, fast in operation and low in cost. It can be used with any coated abrasives, quarried stones or other abrasives as well as with steel balls, shapes and other generally used burnishing media.

Detergency and rinsibility are said to be outstanding characteristics of the new compound, and parts are claimed to leave the barrel free from chips, abrasives, sludge, oil traces or any other foreign matter that might impair subsequent plating or other operations.

Nickel-Plated Aluminum Finds Many Applications in Industry

Development of a process for the nickel coating of aluminum, which finds many applications in industrial manufacturing, has been jointly announced by Hamilton Standard Div., *United Aircraft Corp.*, E. Hartford, Conn., and the *Bart Laboratories Co., Inc.*, Belleville, N. J.

According to Bart Laboratories, the new process solves a major problem in the coating of aluminum with nickel to give a stress-free, hard, yet resilient coating. A synthetic rubber compound developed by Hamilton Standard is used to establish a bond, previously unattainable, between the aluminum and nickel plate. The process is of major importance in protecting duralumin propeller blades from the pitting and eroding effect of spray thrown up in sea landings and takeoffs. Nickel-plated blades emerged from a special Navy testing program unscathed, while unplated blades were severely eroded.

The developers of Alni-Clad claim that the bond between the organic synthetic base and the nickel has an extremely high adhesion or tensile strength and it will stand up under a wide range of temperatures. In the process, the bond material is sprayed onto aluminum to the required thickness. After drying, the piece is then plated with nickel by conventional means, the plate thickness depending upon requirements. With present operational facilities, a component can be clad in approximately 24 hr.

Satisfactory results are said to have been obtained with all aluminum alloys used to date. Finished pieces have a hardness of 400 to 450 Vickers and are stress free. Intricate designs can be given uniform and accurate protection of interior and exterior surfaces with the process, and finished pieces have a semi-bright surface which can be polished chemically or mechanically to a high luster.

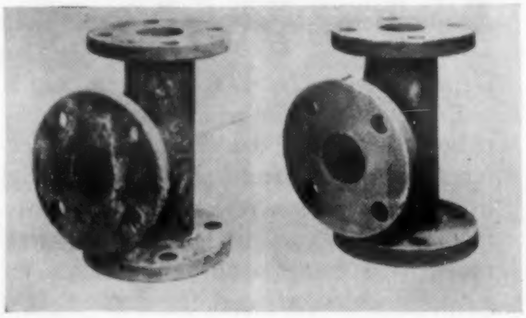
Chemical Treatment Destroys Rust and Phosphatizes Metal

A new chemical treatment that is said to remove rust, tarnish and light oil, and to chemically prepare metals for paint, has been announced by *Octagon Process, Inc.*, 15 Bank St., Staten Island 1, N. Y. Known as Rustclean, the compound is claimed not only to clean the surfaces of steel, iron, aluminum, zinc and cadmium, but also to form a phosphate coating which serves as a base for the organic finishes.

Several types of Rustclean are now available, each designed for different work. The two standard types are Rustclean 12 and 15. Rustclean 12 is designed for a wipe-on process for large parts, or in plants whose equipment or production is limited. The best method of application is by sponge or brush.

Rustclean 15 is a more concentrated compound which is used in an immersion process in a stainless steel vessel (recommended for use at elevated temperatures) or tank line with rubber, polyethylene or asphalt. It is most effective when used at a temperature above 160 F. Standard procedure for cleaning dirty, heavily oiled, rusty parts is to preclean with Octagon 400, an alkali cleaner, rinse, clean with the new compound, and rinse again.

Rustclean types meet all military specifications. Two primary specifications are JAN-C-490, Grade 4 (Rustclean 151) and Grade 5 (Rustclean 152); and MIL-C-10578 (Ord), Type I (Rustclean 153) and Type II (Rustclean 121). The two latter compounds are for immersion and wipe-on processes.



Pipe Tee shown at left before treatment; at right, the same unit after Rustcleaning is free of rust and scale, and has a corrosion resistant phosphate surface.

Small Die Cast Tubular Rivets Afford Economy

These tubular rivets offer the rustproof, corrosion resistant advantages of zinc alloy construction.

Savings achieved through the exclusive die casting techniques of the *Gries Reproducer Corp.*, 780 E. 133rd St., New York 54, have made possible a new line of economically priced small zinc alloy tubular and semi-tubular rivets. These new GRC rivets are said to offer the rustproof, corrosion resistant advantages of zinc alloy construction.

A tensile strength of 45,000 psi assures sufficient strength for low-stress applications not requiring the use of steel or brass. An exclusive company process permits the rivets to be die cast to close tolerances, thus achieving high uniformity.

Standard sizes available for prompt delivery include diameters from 1/16 to 9/64 in. and lengths up to 6/16 in., with oval or flat countersunk heads. Special very tiny sizes as well as ornamented head designs and extra large head diameters can be produced.

Porous Stainless Steel Sheet for Filter Applications

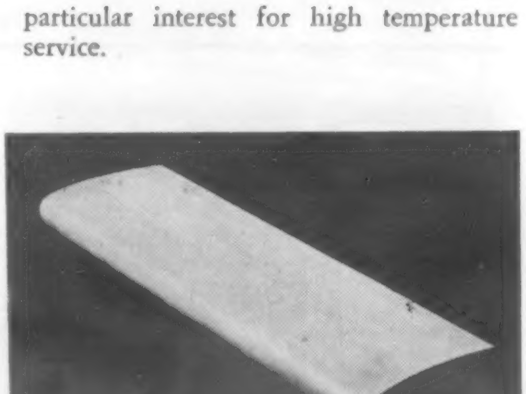
The *Micro Metallic Corp.*, 30 Sea Cliff Ave., Glen Cove, N. Y., has announced the availability of high tensile, smooth surface, porous stainless steel sheets which are expected to widen the application of Micro Metallic porous media into some important new fields.

The new smooth surface porous material is supplied with much higher mechanical properties—with sheer strengths in the range of 60,000 psi. Surface smoothness is said to be comparable with commercial rolled stainless steel sheet finishes.

It is anticipated that sheets of this type of medium will be of particular use in the chemical industries where ready release of collected solids is required. Applications would include use on rotary vacuum filters cleaned by blowback, on vacuum plate filters, fluid catalyst filters where the cake is such that it is not readily discharged by blowback, and similar solids collection service. High pressure filters, particularly those for aircraft service, can be constructed with less weight than heretofore.

Flow capacities of this material range downward from 200 cfm of air per sq ft of filter surface at 10 psi differential pressure, or from 20 gpm per sq ft of water at 10 psi differential. Pore diameters ranging from 20 microns down to zero can be supplied.

Porous material will be stocked in type 304 stainless steel, but is available on special order in other stainless alloys, such as type 309, 316 and 347; also in nickel-base alloys, such as monel, as well as cobalt-base Stellite L-605, which is of particular interest for high temperature service.



Surface smoothness of this porous stainless steel sheet is said to be comparable with commercial rolled stainless steel sheet finishes.

New Materials and Equipment continued

Lightweight Soldering Iron for Pinpoint, High-Speed Work

A new standard-voltage, lightweight, soldering iron designed for pinpoint, high-speed soldering in close quarters, has been announced by the Industrial Heating Dept., *General Electric Co.,* Schenectady 5.

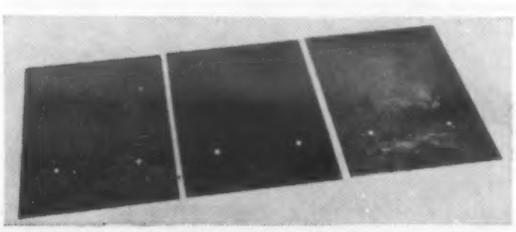
Expected to have wide application by radio, electronic and instrument manufacturers, the iron features a long-lasting, iron-clad, corrosion resistant working surface which, according to company engineers, will bring about a reduction of maintenance costs and production line stoppages due to frequent changing of tips.

The small, slender iron, which is 10½ in. long, has a 5/16-in. shank and a ¼-in. tip. The iron is heated by a G-E Calrod heater which protrudes into the tip, thus giving it an efficient heat transfer. This high heat efficiency is said to result in a quick heat-up and rapid recovery for the iron in operation.

With all parts readily interchangeable for rapid repair, the iron's tip and heater assembly are easily assembled and disassembled from the handle. In addition, the iron is equipped with a flanged plastic handle, so that it can be laid down temporarily without need of a stand.

This new standard-voltage, lightweight soldering iron is designed for use by radio, electronic and instrument manufacturers.

Metal Cleaner Combines Detergent Action and Rust Protection



After three weeks of normal plant exposure, the middle panel, cleaned with EC-51, showed no signs of rusting. The others rusted after two days under the same exposure conditions.

Newest addition to the *Pennsylvania Salt Manufacturing Co.'s* (1000 Widner Bldg., Philadelphia 7) line of emulsion cleaners, Pennsalt EC-51, is a rust-inhibiting organic-type metal cleaner. The product combines powerful detergent action with a high degree of rust protection.

Steel parts cleaned in Pennsalt EC-51 are said to obtain protection from rusting up to 6 weeks under normal plant conditions. Even under unfavorable conditions, protection for two to three days can be expected. The new cleaner is said to be equally efficient in removing soil from all of the nonferrous metals without staining or etching.

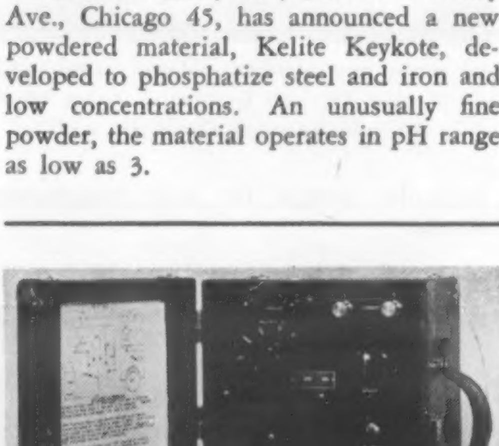
Noncaustic, nonexplosive, and harmless to the skin, the cleaner is used in concentrated or diluted form, and can be applied by both spray and immersion methods. In spray cleaning, a dilution of from 50:1 to 100:1 will apply to practically all cleaning and rust protection applications.

Phosphatizing Compound for Steel and Iron at Low Concentrations

Kelite Products, Inc., 3401 W. Touhy Ave., Chicago 45, has announced a new powdered material, Kelite Keykote, developed to phosphatize steel and iron and low concentrations. An unusually fine powder, the material operates in pH range as low as 3.

No stainless steel equipment is required in the use of this product. Inexpensive black iron tanks can be employed which can be heated by immersion heaters, steam coils, or burners under tank. According to the company, the material will not "sludge out". No screen is necessary in the immersion tanks, nor will there be any powder deposits remaining on the work.

Keykote can be applied by either spray or immersion. It is especially compounded for rapid coatings, normal immersion being 1 to 2 min.



Total weight of Microhm Meter, including internal battery power supply, is 22 lb.

Instrument Checks Cleanliness of Sheet Before Welding

One troublesome factor in the welding of aluminum sheet is the so-called "cleanliness" of the sheets as presented to the welding head. The surface electrical resistance, in microhms, is a measure of the effectiveness of the oxide removal or cleaning process employed.

The new Model 151-S Microhm Meter, currently offered by *J. W. Dice Co.,* 1 Engle St., Englewood, N. J., is said to readily measure the total surface resistance of two sheets, or coupons, when placed between two dummy electrodes. It can accurately measure a resistance as low as one millionth of an ohm, and the readings are practically instantaneous, according to the company.

The instrument scale is 0-75 microhms and is linear. If it is necessary to read higher resistance values than 75 microhms, a selector switch cuts in various multipliers which permit taking measurements up to 750,000 microhms.

(More News on page 144)

Boltaron

PRESSURE FORMABLE SHEET

More than plastic! More than rubber! Boltaron (6100 Series) combines many of the advantages of both these versatile materials

Amazing Formability — Heat Boltaron sheet to approximately 300°F. Use low-cost molds of wood, metal, or composition — simple or complex shapes . . . low-pressure or vacuum forming equipment for shallow draws, simple plug and ring methods for deeper draws.

Tremendous Impact Resistance — A blow that will dent sheet metal or shatter metal castings will leave Boltaron unharmed. A Boltaron tote box can be dropped from a second-story window without injury.

Variety In Color, Size, and Thickness — Boltaron can be produced in any color or shade, and in mirror, matte, and grained finishes. Colors won't scrape off because they are an integral part of the Boltaron sheet. Boltaron is available in standard sheets of 32" x 62" and 35" x 72", in thickness from 1/32" to 1/2".

Thorough technical service on Boltaron is ready for your use at the Bolta Engineering Laboratories.

Service and More Service — Bolta's designing and engineering staff, backed by many years of experience in the plastics field, is ready to work with you!

A special fabricating laboratory is in operation at the Bolta plant in Lawrence, Mass., for your benefit. Special molding and cutting techniques have been developed.

All this engineering is available to you so that you can make the most efficient use of Boltaron. If you do not do your own fabricating, Bolta can give you the name of a qualified fabricator in your vicinity.

Let us answer your problem — Write for illustrated brochure: BOLTA, Box 314, Lawrence, Mass.

BOLTARON (6100 SERIES)

GENERAL SPECIFICATIONS OF STANDARD STOCKS

(Special BOLTARON available on request)

PROPERTY	Temp. °F.	Value	CHEMICAL RESISTANCE:	Temp. °F.	Value
Specific Gravity	70	1.10-1.20	Water Absorption (24 hr. immersion)	70	0.5
Rockwell Hardness "L"	70	28	10% Sulfuric Acid (7 days)	70	0.3
% Elongation at Rupture	70	40	3% Sulfuric Acid (7 days)	70	0.5
% Elongation at Maximum Tensile	70	3	10% Sodium Hydroxide	70	0.3
Ultimate Strength — Tension (p.s.i.)	70	4400	1% Sodium Hydroxide	70	0.5
Young's Modulus in Tension	70	250,000	95% Alcohol	70	3.3
Impact Strength (Izod) (ft. lbs./in. notch)	70	15	Acetone	70	Soluble
(ft. lbs./in. notch)	20	4	Naptha	70	1.5
(ft. lbs./in. notch)	0	1	10% Nitric Acid	70	0.5
			10% Hydrochloric Acid	70	0.2

Specifications will vary as pigmentation and surface finish are changed.

NEW! Boltaron 6200, a plastic of remarkable chemical resistance is available to you, exclusively through H. N. Hartwell & Son, 947 Park Square Bldg., Boston, Mass.

Boltaron

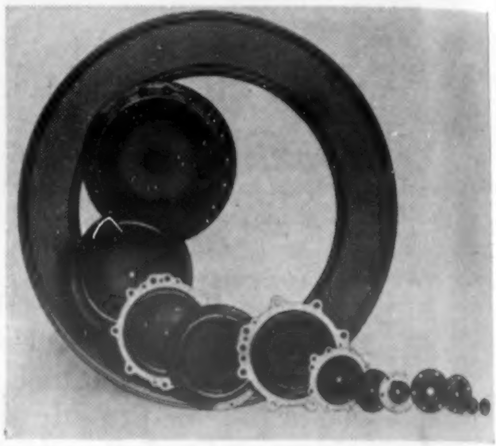
A BOLTA Plastic

Our Custom Molding Division specializes in injection and compression molding of all types. Write direct to this Division for full information

New Materials and Equipment

Special Rubber for Molding Diaphragms

The *Acushnet Process Co.*, New Bedford, Mass., has developed special rubber stocks for molding diaphragms of all types, with or without fabric inserts, from the size of a dime up to 3 ft. in dia



Special rubber compounds with properties that effectively resist fluids and gases, extreme high or low temperatures and prolonged flexing have been used to make these diaphragms.

These special stocks are compounded with properties that effectively resist fluids and gases, extreme high or low temperatures, prolonged flexing, or combinations of these requirements.

The company is fully equipped to produce rubber diaphragms bonded to metal. All diaphragms are made on order to customers' specifications.

New Die Casting Machines Increase Production

Lake Erie Engineering Corp., 700 Woodward Ave., Buffalo, has introduced an improved line of die casting machines which incorporate two exclusive company features, the "Wedge Cam Toggle" and the "Pressure-Pac" injection unit. The new models are said to increase production as much as 15 to 25%.

The "Wedge Cam Toggle" is a self-compensating toggle clamp which automatically takes up clearances in the dies due to contraction and expansion of the molds during production or shut-down periods and, at the same time, engages and disengages easily without binding. Lake Erie has accomplished this by using a circular cam contact surface together

Fig. 2

Fig. 1

Take *YOUR* Casting Problem To A MEEHANITE FOUNDRY

American Brake Shoe Co.	Mahwah, New Jersey
The American Laundry Machinery Co.	Rochester, New York
Atlas Foundry Co.	Detroit, Michigan
Banner Iron Works	St. Louis, Missouri
Barnett Foundry & Machine Co.	Irvington, New Jersey
E. W. Bliss Co.	Hastings, Mich. and Canton, O.
Builders Iron Foundry	Providence, Rhode Island
Compton Foundry	Compton, Calif.
Continental Gin Co.	Birmingham, Alabama
Crawford & Doherty Foundry Co.	Portland, Oregon
The Cooper-Bessemer Corp.	Mt. Vernon, Ohio and Grove City, Pa.
Empire Pattern & Foundry Co.	Tulsa, Oklahoma
Farrel-Birmingham Co., Inc.	Ansonia, Connecticut
Florence Pipe Foundry & Machine Co.	Florence, New Jersey
Fulton Foundry & Machine Co., Inc.	Cleveland, Ohio
General Foundry & Manufacturing Co.	Flint, Michigan
Greenlee Foundry Co.	Chicago, Illinois
The Hamilton Foundry & Machine Co.	Hamilton, Ohio
Hardinge Company, Inc.	New York, New York
Hardinge Manufacturing Co.	York, Pennsylvania
Johnstone Foundries, Inc.	Grove City, Pennsylvania
Kanawha Manufacturing Co.	Charleston, West Virginia
Lincoln Foundry Corp.	Los Angeles, California
E. Long Ltd.	Orillia, Ontario
Otis Elevator Co., Ltd.	Hamilton, Ontario
The Henry Perkins Co.	Bridgewater, Massachusetts
Pohlman Foundry Co., Inc.	Buffalo, New York
Rosedale Foundry & Machine Co.	Pittsburgh, Pennsylvania
Ross-Meehan Foundries	Chattanooga, Tennessee
Shenango-Penn Mold Co.	Dover, Ohio
Sonith Industries, Inc.	Indianapolis, Ind.
Standard Foundry Co.	Worcester, Massachusetts
The Stearns-Roger Manufacturing Co.	Denver, Colorado
Traylor Engineering & Mfg. Co.	Allentown, Pennsylvania
Valley Iron Works, Inc.	St. Paul, Minnesota
Warren Foundry & Pipe Corporation	Phillipsburg, New Jersey

"This advertisement sponsored by foundries listed above."

THE DORRCO V-type Diaphragm Pump (Fig. 1) manufactured by the Dorr Company, Stamford, Conn., was designed for handling sludges, pulps or slimes which contain sizable quantities of solid material. In keeping with their international reputation as builders of dependable and efficient equipment, designed to provide better service life under severe operating conditions, the Dorr Company regularly designs to and specifies Meehanite engineering characteristics.

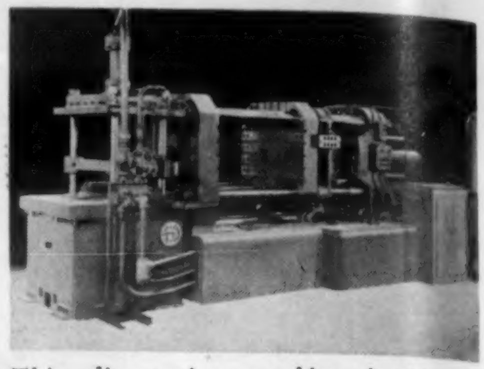
Note that the Meehanite castings (Fig. 2) used in this specific unit reveal the fact that every major component is a Meehanite casting. These castings provide the necessary strength, toughness and resistance to wear and corrosion demanded by the service functions of such a pump.

Write for our new 20-page Pump Bulletin No. 36 which gives complete details not only on pump applications but various specific property tests as applied to impact, erosion, corrosion and wear.

MEEHANITE®

NEW ROCHELLE, N. Y.

New Materials and Equipment



This die casting machine incorporates many major improvements.

with rolls which guide the toggles during engagement and disengagement.

With the introduction of the "Pressure-Pac" injection unit, company engineers have proved that denser castings result, as this new unit provides the necessary pressure to feed the shrink or compress the porosity at the time of solidification of the metal. The unit is arranged for 2 to 1 pressure increase, but the company has also designed special units for higher ratios.

Other features of the new die casting machines include: simplified maintenance of all elements; faster job set-up; "jack screw" pedestal mounting of the injection cylinder which facilitates faster change-over from high or low positions of the injection sleeve. Hydraulic core pulls can be operated on four sides of the platen, and are controlled by an electrical interlock which prevents die jam.

The new line is available in ten models, ranging from 100- to 1000-ton capacity, for casting all the usual nonferrous metals and alloys.

Adhesive Developed for Silicone Treated Surfaces

Silicone coated surfaces can now be strongly adhered with a new adhesive developed by *Polymer Industries, Inc.*, 11-08 30th Ave., Astoria, N. Y. Among the many features claimed for Glas-Weld is that it functions in high-speed gluing machines fully as well as the best standard adhesives. Even in the fastest bottle labeling, carton sealing, bag making and other gluing machines, the adhesives have been successfully operated on a commercial basis.

Silicone coated paper, wood, ceramics and metals have been successfully adhered with this new line of adhesives. The tremendous possibilities inherent in such


"WE'RE FORGING TITANIUM
...THE NEW 'WONDER METAL'...
AT KROPP!"
Titanium has opened a new field of engineering for use where high ratio of strength to weight is essential. Kropp Forge Co. has utilized its great experience to forge this light weight, corrosion resistant metal—both as flat die and drop forgings. We invite your inquiry on forging any new or difficult metal—our engineers are at your call.
KROPP FORGE COMPANY
Chicago 50, Illinois
SUBSIDIARIES: KROPP STEEL CO., Rockford, Illinois
KROPP FORGE ORDNANCE CO., Melvindale, Michigan
K

New Materials and Equipment

finishes are no longer being held back through lack of suitable adhesives for the fabrications of bags, cartons, fiber boxes and cans.

An interesting by-product of this new development is the application of the adhesives to difficult labeling conditions even where no silicone is present. In the past, many forms of glass offered unusual difficulty in adhesion, and no fully satisfactory adhesives adaptable to mass production labeling were available. The Glas-Weld adhesives were found to be adherent to such surfaces as well as to silicone finishes.

Induction Furnace for High-Speed Production of Precision Castings

Developed especially for high-speed production of precision castings, a new mechanically operated induction furnace is currently being offered by *Ajax Electrothermic Corp.*, Trenton 5, N. J. Typical of high-performance parts being cast with the new units are jet engine vanes and blades, compressor parts and small ordnance components.

Operation is said to be extremely simple. At the end of the melting period (12 min. for 5 lb of alloy steel) the preheated mold or investment is clamped di-

This new induction furnace transfers molten metal from furnace to mold in any pre-set cycle.

New Materials and Equipment

rectly to the top of the crucible with a specially-fitted mold-holder. Operation of a control lever causes the furnace to rotate to pouring position. The molten metal fills the mold at the most desirable pouring rate, insuring absolutely uniform precision castings in melt after melt with a minimum of skilled labor.

Induction furnaces are especially suited for melting the complex alloys common to high-temperature and corrosion resistant applications. Temperature and analysis can be controlled within extremely close limits. The electro-magnetic stirring action common to induction furnaces assures even distribution of elements throughout the melt. Since there are no carbon electrodes, there is no chance for carbon contamination.

The new furnace is powered by a standard Ajax-Northrup 20-kw mercury hydrogen type converter, and operates at a frequency of about 30,000 cycles. The converter can also be used to power other melting furnaces, or for various types of heating equipment for heat treating, brazing, etc.

Steam Cleaning Compound Contains No Alkaline Salts

Magnus Chemical Co., South Ave., Garwood, N. J., has announced a new type of steam cleaning compound which is said to greatly improve the cleaning operation wherever steam or vapor cleaning is carried on.

The compound contains no alkaline salts, an important fact, since it removes a serious hazard common to all steam cleaning compounds containing alkaline materials—the conductivity of their solutions and their residues.

Other advantages claimed for the compound are: It is neutral in reaction; it will not dull or streak any good paint; it is noncorrosive. Aluminum and other soft metals which are attacked by alkaline salts are untouched by Magnus 72. The compound is an exceptionally fast and thorough cleaner, and is recommended for use wherever steam or vapor cleaning equipment is in service, without change in setup. Applications include cleaning automotive engines and chassis, airplanes, railroad equipment, factory production machines, paper mill equipment and other oily or greasy metal parts.

In using the compound, two to three quarts of the concentrate are poured into the tank of the steam cleaning machine

MUELLER BRASS CO. ALLOYS FOR AVIATION'S TOUGHEST APPLICATIONS

"803" • Mueller Brass Co. "803" metal is a high silicon iron-copper bronze that is ideally suited for many difficult applications in jet aircraft. "803" metal has unusually good machinability, and it is extremely ductile. It is non-galling and has excellent mechanical properties at temperatures up to 500°F., factors that account for its wide use as roller bearing cages and other specialty parts in jet engines.

"600" SERIES • "600" series are high strength bearing bronzes that do not contain any hard-to-get tin. They can be forged into relatively complicated shapes that are closer to size and require less machining than sand castings. "600" series metals have a low coefficient of friction and a tensile strength 2½ times that of the cast phosphor bronzes. They are highly resistant to wear and corrosion. These properties make "600" series highly desirable for use as parts on hydraulic equipment, actuators and instruments in jet aircraft. "600" series metals are available in standard or special extruded shapes up to 12' mill lengths. There is a "600" series alloy to suit your special bearing metal needs.

TUF-STUF • Mueller Brass Co. TUF-STUF aluminum bronze alloys have found wide acceptance for jet aircraft parts like the rotor for hydraulic pumps and other vital jet engine parts that must stand up. TUF-STUF alloys are corrosion resistant . . . strong and light and extremely long-wearing. They resist oxidation, even at high temperatures. TUF-STUF alloys are available in the form of forgings, rods and screw machine parts. They fill Federal Specification QQ-B-666, Grade B, and several other variations.

For complete information about "803" metal, the "600" series alloys and TUF-STUF, write today to

B2

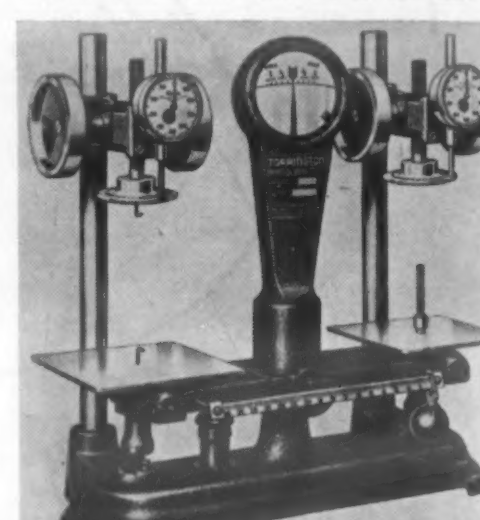
MUELLER BRASS CO. PORT HURON 20, MICHIGAN

New Materials and Equipment

and the tank filled with water. Where solution tank is separate, it is recommended to mix two to three quarts of the compound with 50 gal. of water.

Spring Tester Provides Closer Control in Production of Coiled Springs

A new spring testing machine designed to meet the demand for closer control in the production of coiled springs has been placed in production by *The Torrington Manufacturing Co.*, Box 808, Torrington, Conn. Features of the tester are that it

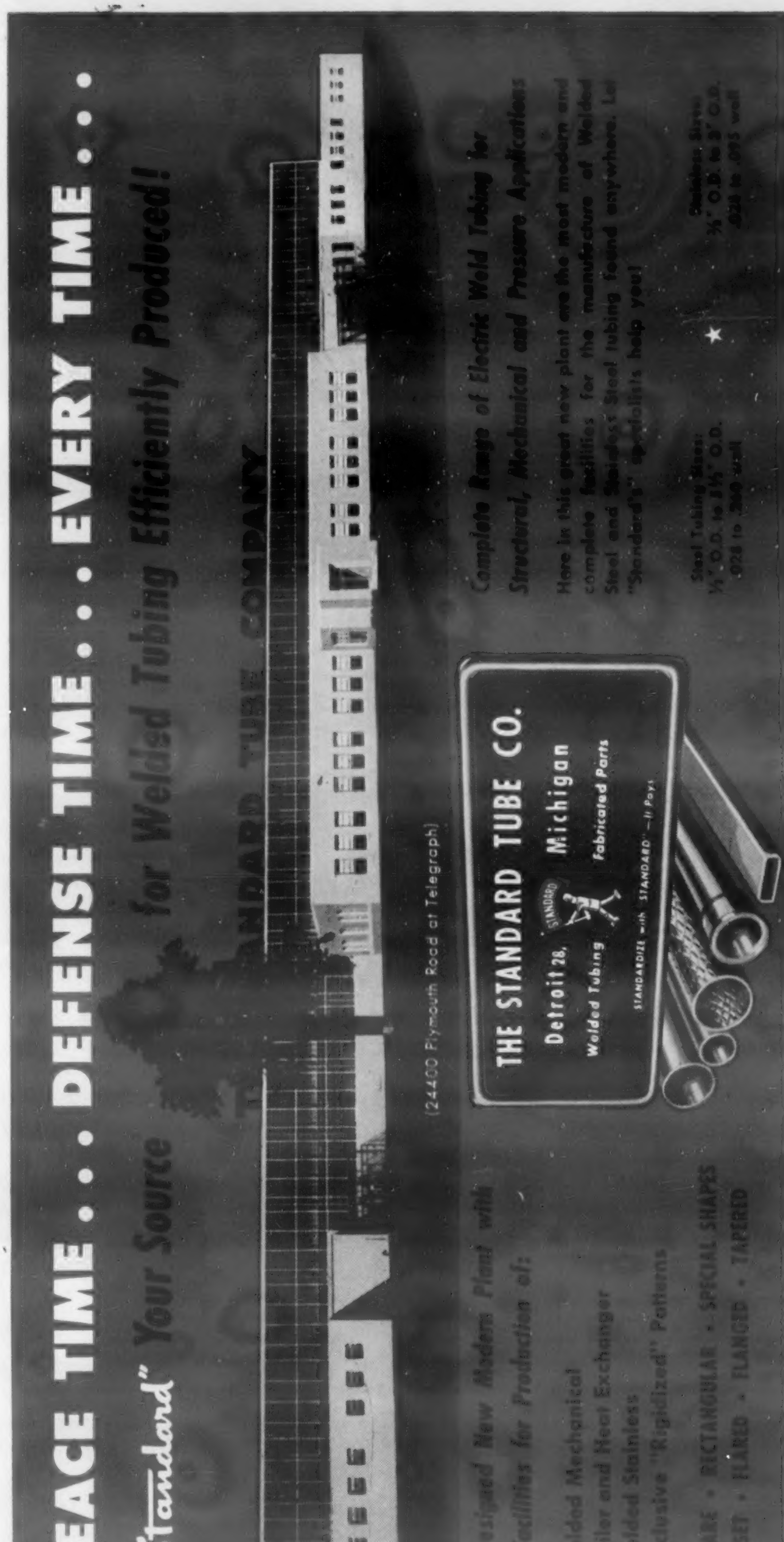


This spring tester features a high degree of sensitivity.

is relatively inexpensive, simple to use and has a high degree of sensitivity.

While the unit is designed to be a rugged production instrument, it is, at the same time, a sensitive device designed to meet new methods of quality control measurement on products in production. It can be used at the operating level by relatively inexperienced personnel. Another particular advantage claimed for the tester is that it measures springs under conditions similar to final usage.

Other uses for the unit beyond the primary use of load testing include: determining the spring gradient, for a check of free height in relation to load, and for the effect of wire size on load. The determination of closeout load when approaching solid height can be readily made. It is particularly valuable for measuring initial tension in extension springs and can also be used for checking the effect of heat treatment and plating. Too, it is said to permit the gath-



New Materials and Equipment

ering of data on spring coiler capability so that the design of springs can be kept within the practical limits of the coiler's performance.

The tester is essentially an even balance weighing scale mounted on a base, with a sponge rubber pad underneath to minimize vibration. The scale has a built-in dashpot to dampen the oscillation of the pointer and pans in testing. Behind the weighing pans are mounted standards which support the spring length measuring devices.

On the two models in production, the smaller measures a load up to the nearest one-hundredth of an ounce and to a capacity of 3 lb. The larger model measures loads to the nearest fifth of an ounce up to 16 lb.

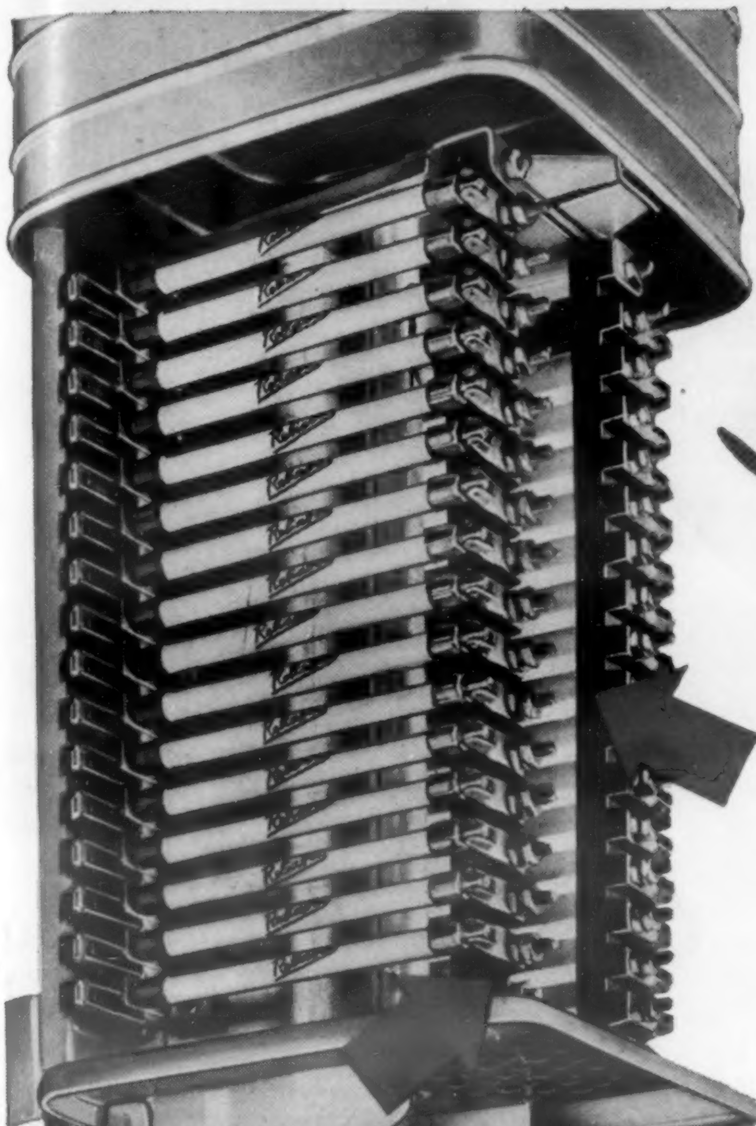
Thermoplastic Molding Compound Retains Toughness at Low Temperatures

Development of a new thermoplastic molding and extrusion compound, which is said to retain its toughness and high impact strength at temperatures as low as —60 F, has been announced by the *Naugatuck Chemical Div., U. S. Rubber Co.*, Rockefeller Center, New York 20.

The new material, known as Kralastic J, is a styrene copolymer. Its initial uses are expected to be primarily military applications where a plastic with low temperature toughness is required. Possible applications include military equipment for Arctic use and for aircraft which reach low temperatures at high altitudes.

Industrial Electric Heaters Offer Many Improvements

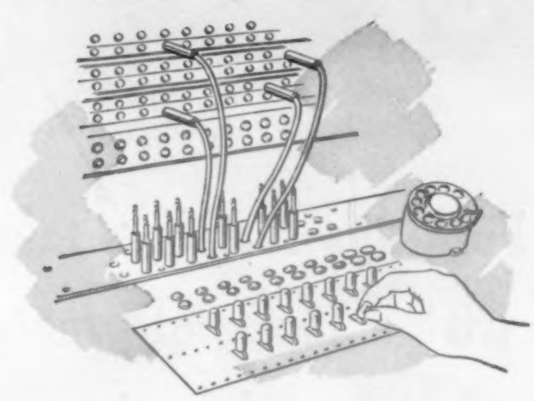
Improvement of two Chromalox industrial electric heaters used in the chemical, plastics, paint, metal working and finishing industries has been announced by *Edwin L. Wiegand Co.*, 7523 Thomas Blvd., Pittsburgh 8. Design of the Chromalox type TBL electric tank heater now includes a vapor-tight terminal box as a standard feature. Heavy duty tubular elements are welded to the sealed, electrical connection housing, and the wiring is



HOW THE COMMUNICATIONS INDUSTRY BENEFITS FROM

Shock-Resistant

G-E RUBBER-PHENOLICS



Cracking Minimized!

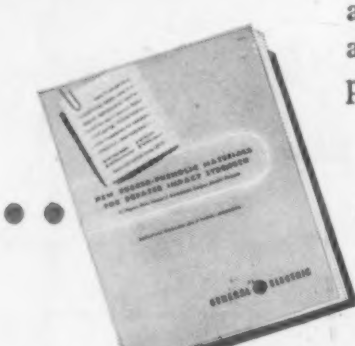
Binding post terminal strips in this telephone cable terminal are now molded of resilient G-E rubber-phenolics—for Reliable Electric Company. Kellog Switchboard and Supply Co. is the molder.

Here's a case where the high internal resilience of shock-resistant General Electric rubber-phenolic compounds helped solve a troublesome cracking problem.

When conventional wood flour-filled phenolics were used for telephone cable terminal binding post strips, it was necessary to support the post strips with metal brackets to minimize cracking from mechanical and electric shock—an expensive solution and one which was detrimental to good insulation.

By a simple switch to G-E *rubber*-phenolic wood flour-filled compounds, these costly and hazardous metal brackets were eliminated. This highly *resilient* plastics has the strength and flexibility to withstand the mechanical and electric shock . . . provides better insulation at lower cost.

This is a typical example of how resilient G-E rubber-phenolics—which have *more than five times* the shock-resistance of conventional phenolic materials—work successfully where ordinary impact materials fail. Designers and molders are using them for a wide variety of industrial applications—textile bobbins, business machine parts, appliance handles—to name a few.



For more information about this rugged family of plastics, write today for a free copy of "New Rubber-Phenolic Materials for Greater Impact Strength." Address: General Electric Company, Section H-2, Chemical Division, Pittsfield, Mass.

You can put your confidence in—

GENERAL ELECTRIC

New Materials and Equipment

This TBL electric tank heater is available with ratings from 3 to 7.5 kw.

brought out to the terminal box through a thick-walled steel pipe.

The new construction is intended to give longer, safer usage of the units in the presence of corrosive and penetrating vapors. Typical uses are in metal working for heating, oil tempering and caustic soda degreasing baths; in foundries, wire manufacturing, molding, stereotyping, for melting tin, babbitt, solder, and similar soft metals; in the chemical and plastics industries for heating transfer mediums, such as molten salt, lead, or oil. The units are available in steel, alloy or stainless with ratings from 3 to 7.5 kw. Heated height ranges from 11⅛ to 43¾ in. and length of feet from 13 7/16 in. to 25 9/16 in.

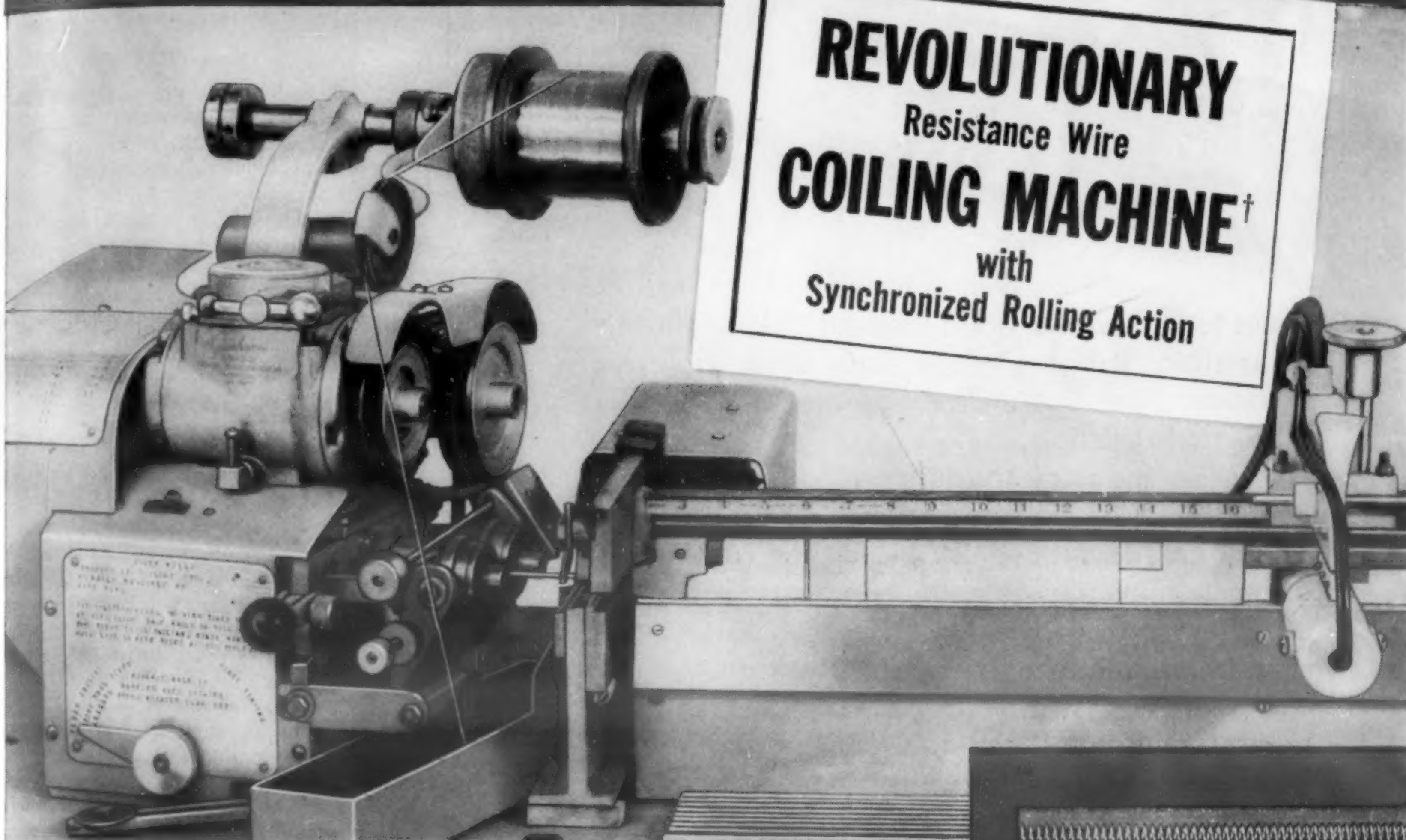
The type ARMT screw-plug unit with explosion-proof or vapor-tight terminal box is also available with wider built-in thermostatic range. With brass or copper construction for water heating, the range is from 50 to 250 F; with steel for oil heating, it is 150 to 550 F. The type used for oil heating has a reduced heat intensity to prevent carbonization of oil on the sheath of the heater. This type of heater is used for process heating in oil refining, paint, chemical and plastics manufacturing. It is available with 2- and 2½ in. standard pipe thread fittings in ratings from 1.5 to 10 kw.

Surface Thermometer Provides Rapid Temperature Checks

Pacific Transducer Co., 11921 W. Pico Blvd., Los Angeles 64, has announced a new surface temperature thermometer for the fast and accurate checking of the outside temperatures of pipes, plastic dies and rubber molds; for checking external temperatures for wall leakage of refrigerators, cold chambers and freezers; for

DRIVER-HARRIS ANNOUNCES . . .

REVOLUTIONARY
Resistance Wire
COILING MACHINE†
with
Synchronized Rolling Action



As producers of the world famous "Nichrome"* and other outstanding electric heating and resistance alloys, Driver-Harris engineers are interested in obtaining application results commensurate with the exceptional advantages their alloys afford. Therefore they have developed a new coiling machine which eliminates wire coiling faults—especially coil irregularity due to work-hardened areas produced during coil formation.

This new machine is the result of knowledge accumulated during forty years of close association with wire coiling problems. Its revolutionary principle of operation—*the synchronized rolling action of all coiling parts*—results in vastly improved performance over that of any other type machine.

Product of long study and a thorough knowledge of the requirements of the industry, this Driver-Harris unit—

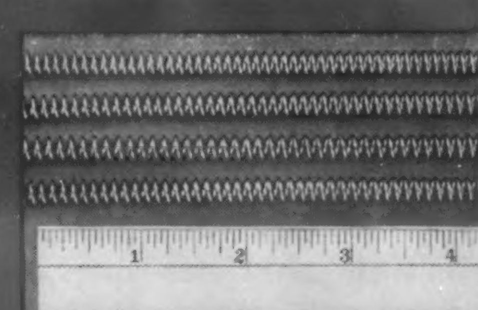
(1) handles the full range of resistance wire coiling normally required, close or open winding (and can be adapted for twin wire coiling);

(2) cuts coil ends clean on all sizes, close or open wound;

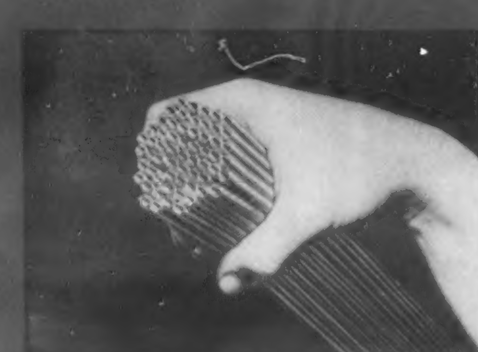
(3) maintains resistance accuracy of cut coils at all times by photo-electric control (variation not exceeding ± 1%);

(4) affords the lowest operational and maintenance costs of any comparable coiling machine.

Standard Model coils #20 to #36 B&S gauge wire. Units for other gauges built to order. Send for illustrated Bulletin C-52, giving full information.



Note even spacing between turns of stretched coils.



Coil ends lie *flat*. No burring or twisting of wire.

*T.M. Reg. U.S. Pat. Off.
†Patent Pending

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Driver-Harris Company

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco

MAKERS OF THE MOST COMPLETE LINE OF ELECTRIC HEATING, RESISTANCE, AND ELECTRONIC ALLOYS IN THE WORLD

New Materials and Equipment

checking the temperatures of journals and other bearings, electric motors and cylinder blocks; also for the checking of residential and industrial wall, ceiling and floor temperatures.

The instrument can be quickly and easily affixed to any flat surface by applying a small amount of silicone grease, which is supplied with the instrument, and sticking the thermometer in place. This silicone grease does not melt and so holds the instrument throughout all ranges of temperature, providing an excellent thermal coupling between the surface to be measured and the instrument.

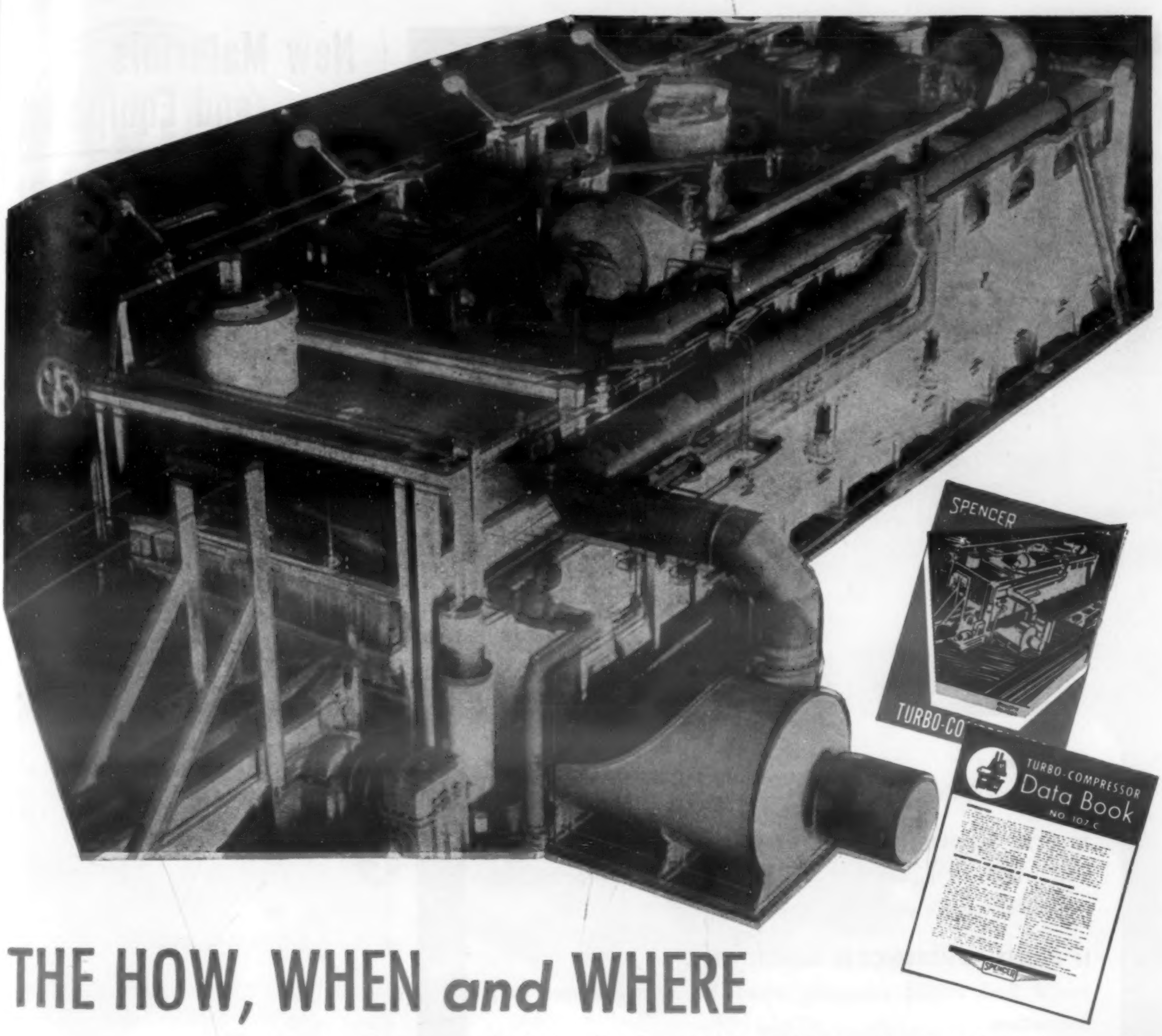
The company also furnishes a small magnetic clamp which will hold it securely in place when applying it on steel dies or other ferrous surfaces. The thermometer can be placed on pipes carrying heated or cooled liquid by affixing it in place by either the clamp or the grease.

According to the company, the instrument has been thermodynamically designed to produce an essentially unilateral thermal instrument which indicates the temperature from the back of the instrument only. A highly reflective evaporated mirror on the dial insures the thermal element against external radiation. The range is 0 to 300 F calibrated in 2-deg. increments.

Gas Filled Metal Rings for Static Seals

United Aircraft Products, Inc., 1160 Bolander Ave., Dayton, Ohio, has come up with a new answer to static sealing requirements in almost every industry. UAP/Willis Metallic O-Rings are permanent, easily installed, hollow metal tubing rings filled with inert gas at 600 psi. They are said to offer positive metal-to-metal

These metallic o-rings offer positive metal-to-metal static seals wherever problems of heat, pressure, corrosive liquids or gases are involved.



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static seals wherever problems of heat, presssure, corrosive liquids or gases are involved.

The rings are dimensionally stable under heat or cold, are not affected by age, and are impervious to oils, gases or aromatic mixtures. They can be installed in present ring grooves, in free machined recesses, or with a special compression limiting device which can be incorporated in the ring. They can be installed without grooves or recesses. They are also said to hold against pressures as high as 20,000 psi and withstand temperatures limited only by the physicals of the metal.

Invented and used in England for many years, the rings have proved successful in high compression diesel engines, air compressor and vacuum equipment, all types of fuel and exhaust systems, retractable undercarriages and other hydraulic applications, as well as a host of marine, automotive and aircraft specialized applications.

Standard rings of stainless steel, mild steel cadmium or nickel plated are available now in experimental quantities in sizes ranging from 11/16 to 40 in. OD in increments of 1/16 in.

Hard Chromium Plating Unit Is Self Contained

The *Cro-Plate Co.,* 747 Windsor St., Hartford 5, Conn., has announced the availability of a new self-contained precision hard chromium plating unit, said to be capable of meeting all electroplating requirements. With this plater, shops large or small can effect immediate and substantial savings by doing their own plating on their premises. Tests prove that cutting tools, gages, dies, molds and machine wear parts average 300% longer life, when chromium plated, than nonplated counterparts.

The bench model plater requires a space of only 2 by 3 ft, yet all controls, transformers, rectifiers, switches and heating elements, including the plating tank, are contained within the unit. A current source and duct outlet are the only connections required for immediate operation.

Construction of the Cro-Plater 100 is angle-iron for rigidity. The tank is lead-lined Armco iron, and this lining can be changed for the plating of other metals. Tank heating is accomplished by easily-removed 1500-watt electric heaters. Rectifiers are horizontally-forced air cooled by

New Materials and Equipment

This hard chromium plating unit is said to be capable of meeting all electro-plating requirements.

a fan, and bath temperature is thermostatically-controlled. All circuits are overload-protected with self-resetting, heater type switches. The unit provides a rectified source of d.c. power up to 100 amps at 0 to 12 v.

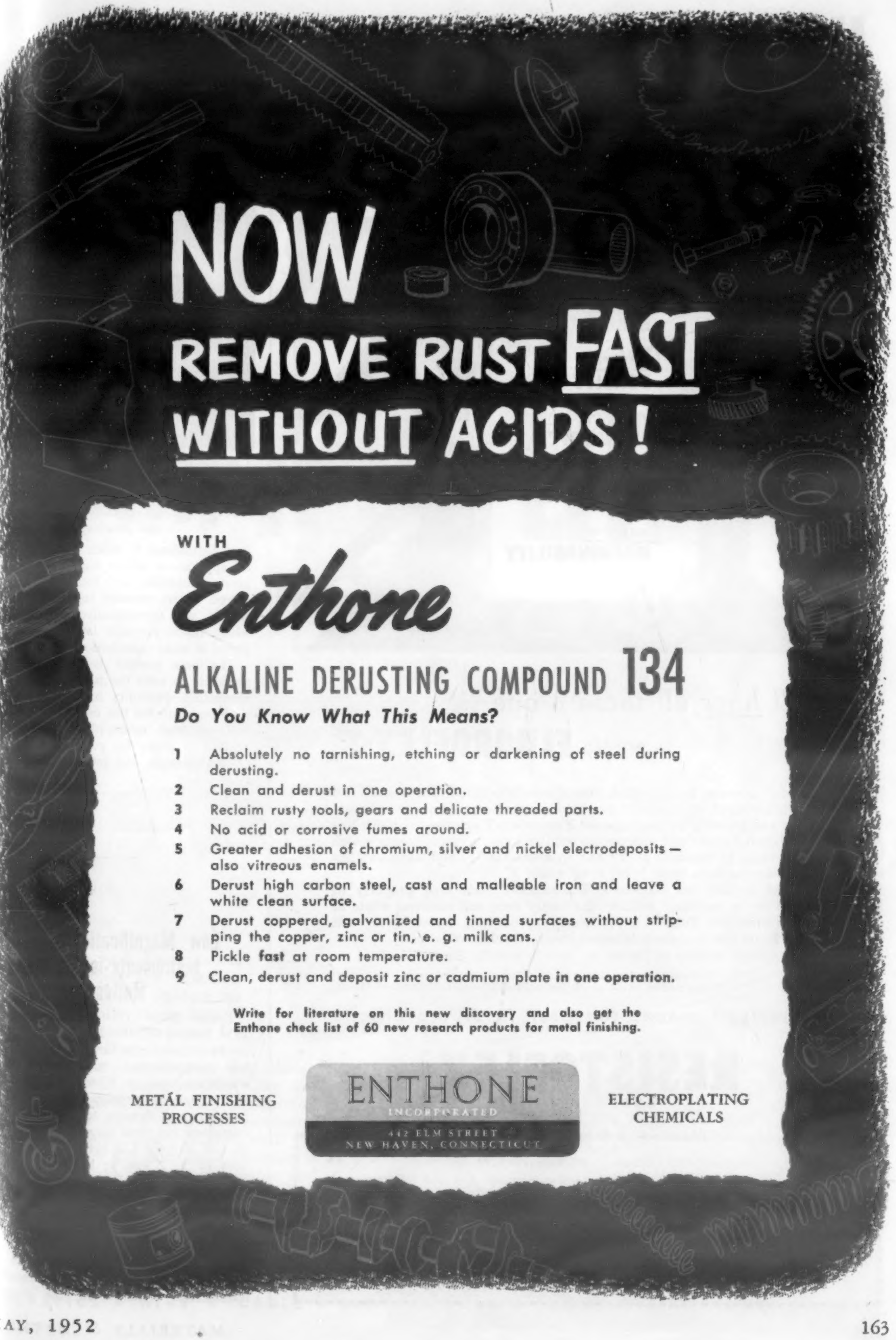
Fiber Glass Plastic Sheet Available in Fractional Dimensions

Broad increase in size range of A3A fiber glass plastic sheet material has been announced by *The Dynakon Corp.*, 5509 Hough Ave., Cleveland 3. Previously, thickness range was in only four sizes to ½ in. Now, sheet is available in fractional dimensions from 1/16 to 1½ in. thick by 18 by 28 in. Special sizes to 2½ in. are also available.

The material has unusual electrical and chemical properties as well as high strength. Tensile is 11,900 psi; compressive strength, 14,300; impact is 10.3 ft-lb; dielectric, 325 v per mil; arc resistance, 120 sec; and moisture absorption is only 0.39%. The material is also resistant to mild alkalies and most acids and salts.

Rubber-Phenolic Varnish Provides High Impact, Greater Flexibility

A new rubber-phenolic varnish which is said to permit the manufacture of laminated plastics having two to three times the impact strength of those made with conventional varnishes has been announced by the Chemical Div., *General Electric Co.*, Pittsfield, Mass. 12359 has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REMOVE RUST FAST
WITHOUT ACIDS!
WITH
Enthone
ALKALINE DERUSTING COMPOUND 134
Do You Know What This Means?
1 Absolutely no tarnishing, etching or darkening of steel during derusting.
2 Clean and derust in one operation.
3 Reclaim rusty tools, gears and delicate threaded parts.
4 No acid or corrosive fumes around.
5 Greater adhesion of chromium, silver and nickel electrodeposits — also vitreous enamels.
6 Derust high carbon steel, cast and malleable iron and leave a white clean surface.
7 Derust coppered, galvanized and tinned surfaces without stripping the copper, zinc or tin, e. g. milk cans.
8 Pickle fast at room temperature.
9 Clean, derust and deposit zinc or cadmium plate in one operation.
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Laminates made with the new rubber-phenolic varnish have outstanding flexibility and resistance to impact. Here rubber-phenolic laminates are flexed without breaking.

been formulated to tackle tough mechanical applications where higher impact and greater flexibility and toughness are required. Gears, shuttles, tubing and castor wheels are representative of the jobs where rubber-phenolic laminates are expected to make contributions.

The new product is said to enable phenolics to enter the paper-coating field. Heretofore, phenolics have been considered too brittle for this use. Tests indicate, however, that rubber-phenolic varnishes applied to paper for packaging give increased strength and improved resistance to moisture.

Low Magnification Strain Instruments for Large Motions

Tinius Olsen Testing Machine Co., 1054 Easton Rd., Willow Grove, Pa., is currently offering a new line of C-Type low magnification strain instruments which are used to detect large motions of specimen deformation in tension, compression and flexure testing. The C-1 instrument has three magnifications of 10, 20 and 40; the C-2 provides magnifications of 1, 2 and 4; the C-3 provides magnifications of 2½, 5 and 10. When used in conjunction with the S-Type extensometer, complete stress-strain curves can be produced automatically without stopping tests.

The instruments transmit signals by means of special Atcotran differential transformers which rotate the recorder

New Materials and Equipment

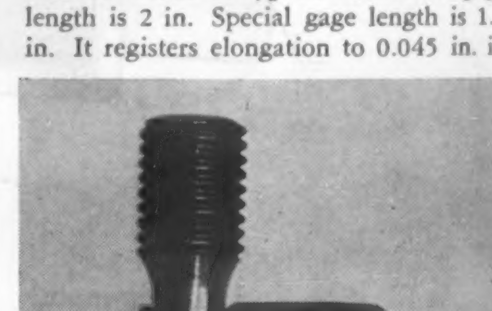
drum in direct proportion to the motion measured (usually crosshead differential travel). These instruments can also be used as a deflectometer.

Weighing only 2½ lb (4 by 4 by 4½ in.), the instrument can be placed either on the table, crosshead or platform of the testing machine. C-Type instruments are guaranteed to return to zero, since backlash eliminators are built in. Calibration is based on fixed linear distances of the lever, and to the same precise standards as the Olsen Model 51 recorder.

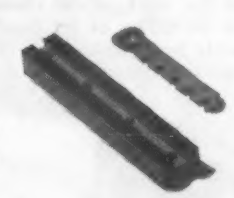
Simplified Extensometer Indicates Elongation Directly

A newly designed extensometer which indicates the elongation of metallic and plastic specimens in tension testing directly, without a multiplying lever, has been announced by *National Forge and Ordnance Co.*, Testing Machine Div., Irvine, Warren County, Pa.

The instrument, which weighs only 7 oz, attaches to the specimen by spring clamps which are opened or closed while it is held in the palm of the hand. It readily adjusts to take wire, sheet, plate or round specimens up to a maximum thickness or width of ½ in. Standard gage length is 2 in. Special gage length is 1.4 in. It registers elongation to 0.045 in. in



This extensometer readily adjusts to take wire, sheet, plate or round specimens up to a maximum thickness.



New Materials and Equipment

dial gradients of 0.0002 in. The larger-sized dial on the jeweled indicator is said to permit accurate readings to 0.0001 in.

Sealer Applied to Surfaces Before Spotwelding

An aluminum-colored "weld-through" sealer originally used in auto manufacturing has now been made available to industry by the Adhesives and Coatings Div., *Minnesota Mining and Manufacturing Co.,* 411 Piquette Ave., Detroit 2. The sealer is applied to surfaces before spot welding, thus eliminating the need for a sealing operation after welding. It does not interfere with the welding operation.

A heavy paste-like material that is said to have the unusual property of resisting the heat and pressure of welding without splattering or burning, the sealer is soft enough to uniformly squeeze away from the bottom of the weld when electrode pressure is applied, without flowing away excessively. Auto manufacturers use the material to seal the spot-welded joint between the roof and side panels, to seal along drip moldings, and to seal the joint between the rear quarter panel and wheel housing.

The sealer is said to shut out air, dust and moisture; withstand paint oven temperatures up to 475 F. It is not brittle at -10 F, does not support combustion, and protects metal from corrosion. It is applied with a hand caulking gun or pressure extruding equipment, or it can be applied in small quantities with a scraper or putty knife.

Chromium Plating Unit Increases Tool Life

A 250-amp Chromaster unit has been added to the *Ward Leonard Electric Co.'s* (Mt. Vernon, N. Y.) line of industrial chromium plating equipment. The new production tool is designed for industrial chromium plating small tools or parts in large quantities, or generous sized parts with areas to 125 sq in.

With Chromaster and Chromasol, a new chromium plating solution, normal life of cutting tools, wear parts and dies is said to be increased up to ten times. According to the company, chromium plating with the new process is said to be fast, economical and simple in operation. Aver-


ALUMINUM
MONEL*
BRASS
STEEL
INCONEL*
NEED METALS?
STAINLESS STEEL
NICKEL*
COPPER
Sheet, Plate, Tube, Pipe, Wire, Rod and Bar, Extrusions, Structural Shapes .. and the following INDUSTRIAL PRODUCTS: Fasteners, Tube Fittings, Pipe Fittings, Valves, Silver Brazing Alloy, Welding Material, Solder, Castings, Tube Expander Equipment, Liquid Plastic Protective Coating, Metallic Caulking Compound, Aluminum Metal Trim, Waterproof Barriers, Nails, Handrail Fittings, Low Melting Alloys, Aluminum Jacketing, Wire Cloth and Rope, and "O" Rings.
Precision Equipment for Shearing and Slitting.
*Not stocked in Kansas City or St. Louis territories.
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New Materials and Equipment

This industrial chromium plating unit is designed for plating small tools or parts in large quantities or generous sized parts with areas to 125 sq in.

age plating time is 3½ min for cutting tools, and chromium cost averages just a few mils in most applications.

Individual floor-mounted plating tank and power unit are designed to minimize installation costs and to conserve plant floor space. Power unit contains a built-in selenium rectifier complete with instrument control panel and controls for accurately regulating the rate of chromium deposit.

Low-Cost Plasticizers for Vinyl Compounds Increases Stability

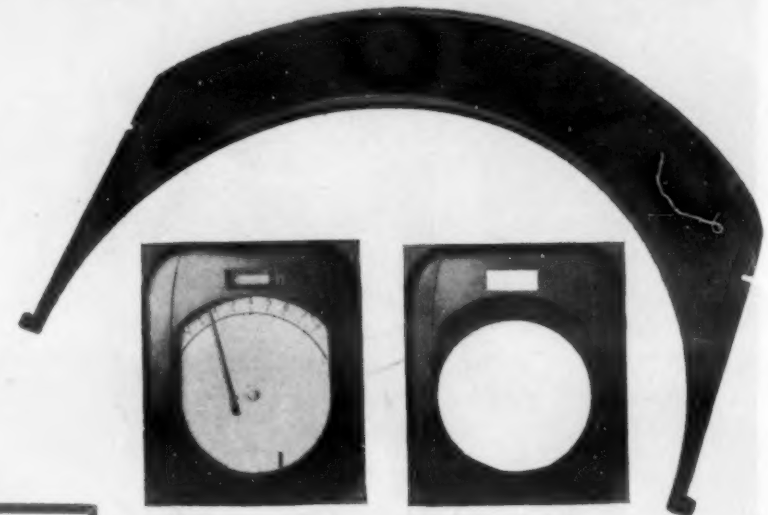
The *Rohm & Haas Co.*, Washington Sq., Philadelphia, has announced the development of Monoplex S-71, a new, low-cost plasticizer for vinyl compounds. Light and clear in color, of low volatility and viscosity, able to impart low brittle point values, Monoplex S-71 is said to offer two important advantages: it is inexpensive, and effectively increases the stability of vinyl resins under heat and light.

The plasticizer is recommended for use in upholstery sheeting, fabric coatings, light-weight film, garden hose, electrical jacketing, dispersion compounds for casting and slush molding, injection molding, and rigid or semi-rigid vinyl products.

Also announced by the company is an inexpensive primary vinyl plasticizer of low volatility. Designated Monoplex S-38, this high molecular weight monomeric plasticizer is said to exhibit both good efficiency and satisfactory processing characteristics. It can be employed as the sole plasticizer in blends with the Paraplex

They found new ways to KEEP COSTS DOWN

ELECTRIC CORN POPPER
Popex Inc.



FLO-METER DOOR
Penn Industrial Instrument Corp.

ONE-PIECE CASE
L. C. Smith and Corona Typewriters, Inc.

COLOR SLIDE VIEWER
The FR Corporation

...with custom-molded DUREZ phenolics

From all directions the news rolls in from Durez phenolics users ... and it's *good* because it's news of costs saved in product development, improvement, and redesign ...

Formerly 19 assembly operations . . . now six.

Inexpensive insert makes "new" model. Tool and jig requirements slashed. Finishing eliminated.

Reports like these point up a thought to have in mind when *your* products are in the making . . . it pays to talk things over with your custom molder. He has the know-how that translates new ideas into molded Durez. His equipment is large enough for big moldings and is getting larger all the time.

Of course the plastic must have good flow and strength properties to permit wide freedom in design for molding. Durez has both . . . and it offers your engineers eight distinct classes of phenolics among which they can select the mechanical, electrical, and chemical properties that fit their specifications.

Our technicians can aid you with specialized knowledge of these materials and their use. Call them any time.

Our monthly "Durez Plastics News" will keep you informed on industry's uses of Durez. Write, on office letterhead, to Durez Plastics & Chemicals, Inc., 1405 Walck Road, North Tonawanda, N. Y.

PHENOLIC PLASTICS THAT FIT THE JOB

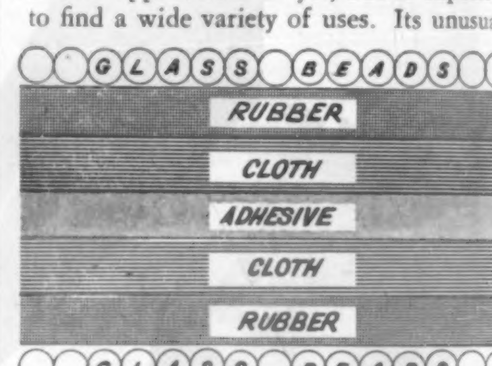
New Materials and Equipment

plasticizers, and in compounds containing low-cost secondary plasticizers and extenders. Because of its rather dark color, Monoplex S-38 is generally suitable for only filled and pigmented compounds. As a primary plasticizer for such materials it offers considerable formulating economies without substantial sacrifice in quality.

It is recommended for use in pocketbook stocks, gasket compounds, flooring, extruded molding, welding and jacket stocks.

New Beaded Fabric Material Offers Interesting Possibilities

A new beaded fabric, "Spherekote", has been announced by *Minnesota Mining and Manufacturing Co.*, 900 Fauquier St., St. Paul 6. The new construction has no known applications as yet, but is expected to find a wide variety of uses. Its unusual



This new beaded fabric, "Spherekote", is made by laminating two sheets of oil resistant material back-to-back.

characteristics include a coating of millions of microscopic glass spheres on each side, and an inner lining of cloth and rubber that compresses to provide uniform friction and tightness in use.

The material is made by laminating two sheets of the oil resistant material back-to-back. It has a thickness of approximately 55 mils.

Washers, one example of the product's possible use, were recently tested between the folding joints of a car's convertible top. For this use the material's glass-beaded surfaces provided "very low coefficient of friction, distributed pressure evenly, and showed no evidence of scoring." In addition, the test showed that the material could be used with or without a lubricant. When a lubricant was used, minute spaces between the spheres acted as a reservoir for the oil.

Firms wishing to conduct their own experiments with the new material may obtain sample 4- by 6-in. swatches on request.

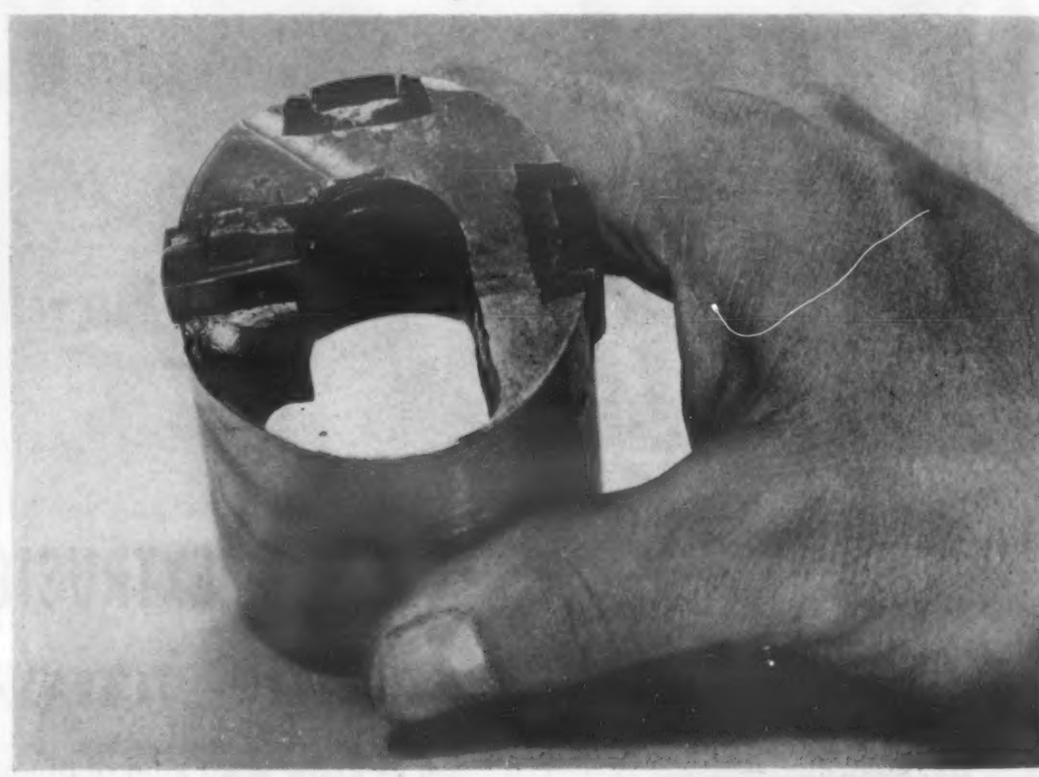
Trepanning Speeds Boring Holes in Heavy Metal Sections

by FRED W. LUCHT, Development Engineer, Carboloy Dept., General Electric Co.

● THE PROCESS OF producing reasonably large holes by cutting a cylindrical groove and removing the center as a solid core, instead of removing all the metal within the i.d. in the form of chips, is known as trepanning. It is only in recent years, apparently, that the principle has been applied to the machining of accurate bores in metals. Of particular interest at present is the application of the process to the drilling of gun barrels at a rate impossible with boring tools or conventional spade drills. A trepanning head used for this operation is shown in the accompanying figure. Holes up to 30 or 40 ft or more in length, and up to 4½ in. in dia have been produced in steel forgings in this manner, and to tolerances of only a few thousandths as to concentricity and diameter. The advantages of the process, however, are not confined to deep holes. The process can be applied equally well to the producing of through holes in such parts as gear forgings, etc., thereby greatly reducing machining time. Accuracies in general will be better than when drilling, provided the equipment used is satisfactory.

In general, the savings in time obtainable by deep-hole trepanning with carbides as compared with producing the same hole with high-speed steel drills may run as high as 95%. Part of this saving, of course, is due to the higher cutting speeds and feed rates made possible by the carbide tip used on trepanning tools. However, the major part of the saving is still due to the simple fact that far less metal has to be removed in the form of chips.

Trepanning is particularly suitable for carbides, for the following reasons:



A typical trepanning head used for the drilling of gun barrels.

1. The long life of the carbide insures continuity of cutting, as well as maintenance of closer tolerances as to diameter at the end of the bore as compared with the diameter at the beginning.

2. Higher cutting speeds and feed rates are possible with carbides.

3. The trepanning cutter body carrying the trepanning cutter blade must be protected against wear as it bears against the i.d. of the hole. Here again, carbide wear strips provide an excellent answer.

4. Proper carbide speeds can be obtained over the entire cutting edge of a trepanning tool. (The dead center on a spade type drill makes it unsuitable for carbides).

(Continued on page 176)

It Costs No More to be Sure!

The **CERTIFIED ZINC ALLOY PLAN** is your assurance that the castings you obtain have been produced in a plant maintaining proper alloy control.

Regular sampling and analysis certify that the alloy used has been proven to be "on grade."

Why not be certain?

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Advance Pressure Castings, Inc., Brooklyn, N. Y.
Advance Tool & Die Casting Co., Milwaukee, Wis.

Badger Die Casting Corp., Milwaukee, Wis.

Central Die Casting & Mfg. Co., Inc., Chicago, Ill.
Cleveland Hardware & Forging Co., Cleveland, Ohio
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Continental Die Casting Corp., Detroit, Mich. Division of F. L. Jacobs Co.
Crown City Die Casting Co., Pasadena, Calif.

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Doehler-Jarvis Corp., Toledo, Ohio
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Federal Die Casting Co., Chicago, Ill.

Globe Imperial Corporation, Rockford, Ill.
C. M. Grey Mfg. Co., East Orange, N. J.

Heick Die Casting Corporation, Chicago, Ill.
Hilfinger Corporation, Toledo, Ohio
The Hoover Company, North Canton, Ohio

Kamin Die Casting & Mfg. Co., Chicago, Ill.
Kiowa Corporation, Marshalltown, Iowa
Paul Krone Die Casting Co., Chicago, Ill.

Madison-Kipp Corporation, Madison, Wis.
Milwaukee Die Casting Co., Milwaukee, Wis.
Monarch Aluminum Mfg. Co., Cleveland, Ohio
Mt. Vernon Die Casting Corp., Mt. Vernon, N. Y.

New Products Corp., Benton Harbor, Mich.

Paragon Die Casting Co., Chicago, Ill.
Parker White Metal Co., Erie, Penna.
Precision Castings Co., Inc., Syracuse, N. Y.
Precision Castings Co., Inc., Cleveland, Ohio
Precision Castings Corp., Inc., Chicago, Ill.
Pressure Castings, Inc., Cleveland, Ohio

Racine Die Castings Co., Racine, Wis.

St. Louis Die Casting Corp., St. Louis, Mo.
Schultz Die Casting Co., Toledo, Ohio
Sterling Die Casting Co., Inc., Brooklyn, N. Y.
Stewart Die Casting Div., of Stewart Warner Corp. Bridgeport, Conn.
Stewart Die Casting Div., of Stewart Warner Corp. Chicago, Ill.
Stroh Die Moulded Casting Co., Milwaukee, Wis.
Superior Die Casting Co., The, Cleveland, Ohio

The Tool-Die Engineering Co., Cleveland, Ohio
Twin City Die Castings Co., Minneapolis, Minn.

Union Die Casting Co., Ltd., Los Angeles, Calif.
Universal Die Casting Co., Los Angeles, Calif.

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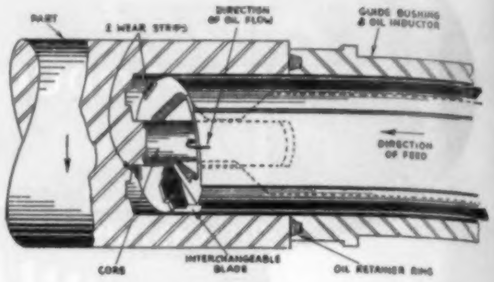

Cut-away diagrammatic sketch showing trepanning head slightly retracted after starting a cut.

To give an idea of the savings possible by trepanning instead of drilling, the following example may be of interest:

Work—18 ft long, rough turned steel forging
Hole—2 13/16 in. to be produced entire length
Feed—0.008 in. per revolution
Speed—550 SFPM (747 rpm) at outer edge of tool
Accuracy—Hole held within 0.003 in. for size, and within 0.012 in. for alignment.

At the speed and feed used, total feed was 6 in. per min, giving a total cutting time of only 36 min. This, compared with an established drilling time of 15 hr when using high-speed steel spade drills including time required for three drill changes.

Converting for Trepanning

At the present time there are few machines built in this country which were designed specifically for trepanning work. However, it is entirely feasible to convert existing deep hole boring machines or lathes to such work. Chief requirements for a trepanning machine conversion are:

1. Adequate motor horsepower. In the example above, 46 hp was required. 60 hp or more is usually desirable for good performance, depending on hole size and material.

2. An oil pump capable of delivering 25 gal per min or more, at a pressure of at least 175 psi, was required for the above mentioned job. The volume of oil required will vary, of course, with the hole size.

3. A carriage fixture to support and permit accurate feed of the tube on which the trepanning tool is mounted.

4. An oil inductor bushing and support which also provides an oil seal at the entrance end of the bore.

5. Steady rests to support the work.

6. Centralization of all electrical controls and indicators at or near

(Continued on page 178)

The best of a bumper crop . . .

HIGH PRODUCTION OF HEAVY-DUTY BUMPER GUARDS CALLS FOR SHARON* QUALITY DEEP-DRAWING STEELS

Tough, shock-absorbing bumper guards must be decorative as well as functional. Their manufacture demands heavy gauge steel that will take a deep draw easily without showing strain.

Many leading manufacturers of bumpers and bumper parts specify Sharon bumper steels whenever possible, for their experience tells them they can expect uniform top quality steel that can be easily deep drawn at mass production speeds without a trace of strain to blemish the finish.

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point of chip outlet.

7. Variable speed control for the motor.

8. Gearless headstock.

9. Cutting fluid temperature and oil pressure gages.

Horsepower requirements, of course, are governed by rate of chip removal. The high power required is due to the ability of the carbide to remove chips so rapidly.

While 175 psi is given here as a minimum for oil pressure, higher psi values are frequently desirable. Much work has been done already in trepanning at pressures as high as 200 to 400 psi. The higher pressures, of course, require better oil seals.

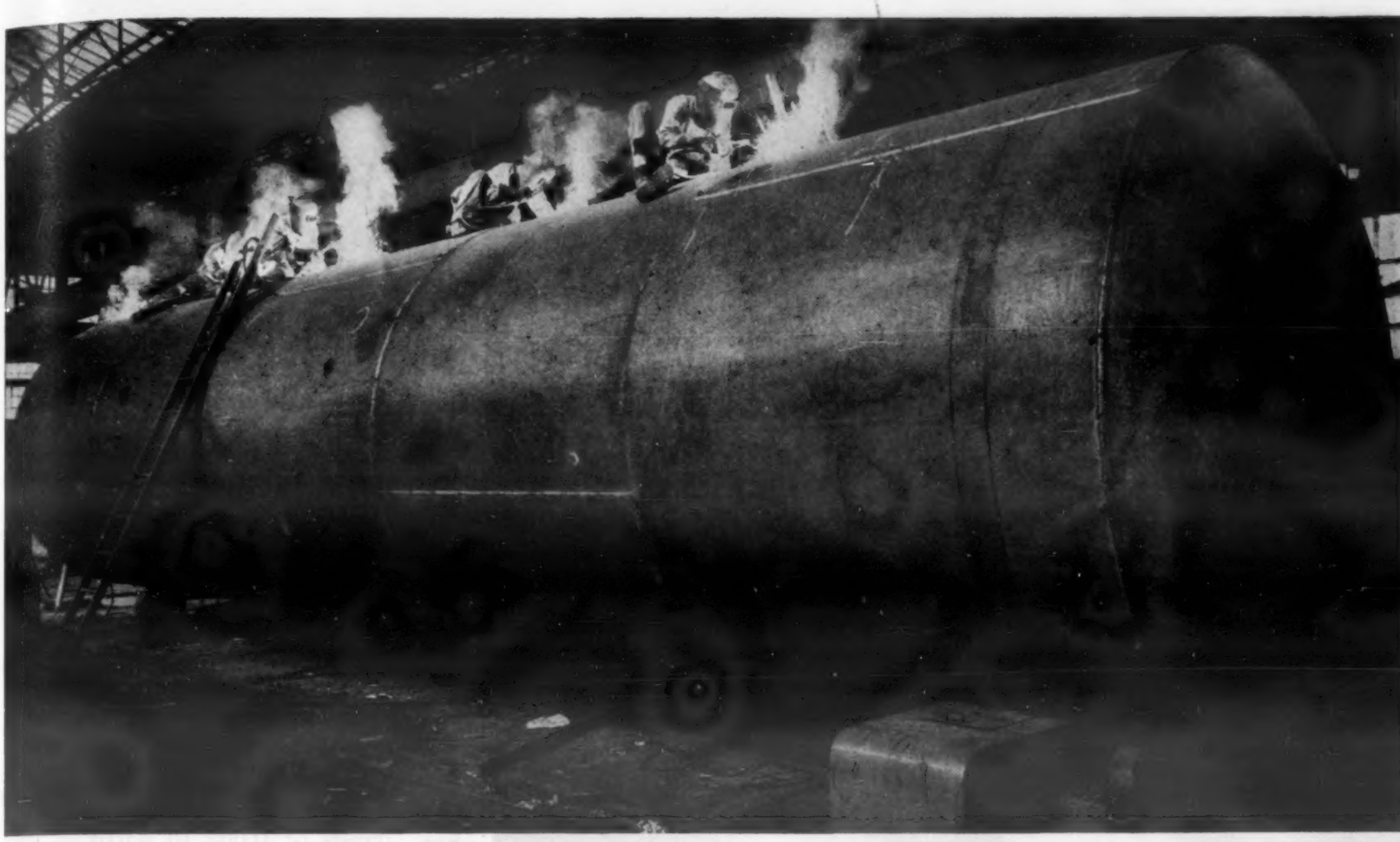
Uniform control of tool feed presupposed the use of accurate lead screws to feed the tool into the work as the work revolves. If a machine considered for adaptation to trepanning has been used a great deal for one length of work which required the carriage to move over the same place many times, it may be found that because of lead screw wear in this spot the screw should be replaced to insure uniform feed over the entire travel of the carriage.

Trepanning Cutter

The trepanning cutter head is attached to the non-revolving drive tube. Two types of cutter blades are currently used, a 3/4-in. wide cutter blade for holes 1 3/4 in. up to as large as 8 in.; cutter blades 1 1/4 in. wide have been successfully applied to trepanning of large sized bores. Selection of cutter blade size depends considerably on operating conditions and horsepower available. With the 3/4-in. cutter blade, oil is fed under pressure to the cutter head through the space between the drive tube and the i.d. of the hole and is discharged along with the chips through the space between the i.d. of the tube and the core. With the larger cutter blade, the flow is reversed, since it has been found that discharge of the cutting fluid and chips around the periphery of the drive tube is advisable when trepanning large holes.

Grade 78 has been found satisfactory for the tip for trepanning any steel within a 200 to 400 Brinell hardness range. Best material for the wear strips appears to be grade 78. Best cutting speeds range from about 600 sfpm for steels in the 200

(Continued on page 180)



WORTHINGTON TURNING ROLLS IN OPERATION move this big tank at exactly the right speed for the most efficient downhand welding. This equipment often increases output as much as 50% because downhand welding with heavier electrodes does the job with one pass instead of two or three.

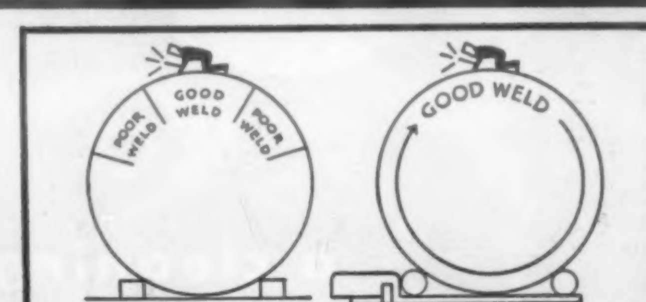
A way to lower your welding costs as much as 50%

If you are welding cylindrical vessels of any size, you can lower costs and increase welding footage as much as 50% with Worthington Turning Rolls.

Your welders can produce more *real footage* by eliminating time wasted in manually turning the vessel or waiting for crane or hoist service.

You'll get neater, stronger welds and less rod waste, too. The Worthington Turning Roll power turns the vessel at selected welding speeds for quickest spotting of longitudinal seams and continuous welding of circumferential seams. All welds can be made by the convenient downhand method with the economies that result from larger electrodes used.

Where can you see a Worthington Turning Roll at work near you? Just write Worthington Corporation, formerly Worthington Pump and Machinery Corporation, Dunellen, N. J., for this information or for Bulletin 210C.



(Figure 1) (Figure 2)

WHY WORTHINGTON TURNING ROLLS INSURE BETTER WELDS

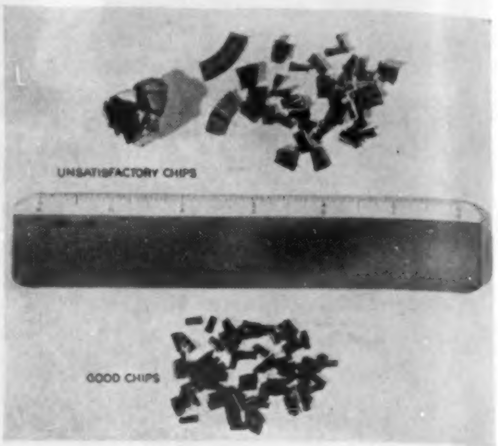
Unless the work is turned continuously, good downhand welding is obtainable only in small area (Fig. 1). With a Worthington Turning Roll, downhand welding is assured for the complete circumferential seam (either by manual or automatic welding) (Fig. 2).

WORTHINGTON'S LOW-SLUNG DRIVE MECHANISM permits unobstructed loading from either end of turning rolls. The high-efficiency and smooth operation of Worthington power rolls (lower right) and idler rolls (upper left) result from long and varied experience in building equipment for welding cylindrical vessels.

Y.1.3

WORTHINGTON

Welding Positioners
Turning Rolls



Chips produced in trepanning should be well broken up and as near uniform in size as possible. Good chips are shown at the bottom. Unsatisfactory chips are shown at the tip. Chip breaker design is particularly important in trepanning work.

to 250 Brinell range to approximately 400 sfpm for those up to 400 Brinell. These speeds are for the outside edge of the blade.

Feeds of 0.006 to 0.010 in. per revolution have been found to work very well, but best feeds for each type of job may require some modification. The important thing is to produce a fairly heavy chip. This reduces cutter blade wear. The chips, however, should be broken up until they are small enough to pass freely through the discharge space. Feed should not be reduced if speed is increased, or vice versa. In some instances, although the chips theoretically may be small enough for easy passage, the coolant pressure must be increased to flush them out properly. This is especially true when nearing the end of extremely deep holes.

It is important that the correct cutter blade grind be secured right at the start. Wear strips are cylindrically ground in position before inserting the blade. The cutter blade is also cylindrically ground (to a slightly larger diameter, as shown after assembly in place.)

Trepanning speed depends on material being machined, of course. With material of 275 or 375 Brinell, cutting speeds of 500 to 600 sfpm (at bore diameter) have been found to work well. Somewhat higher speeds can be used for materials of lower hardness.

In some cases, trouble has been experienced from extremely fine particles carrying through the conventional filter. Use of a special filter employing Carboloy permanent magnets has been found helpful in such cases by keeping these chips from getting into the pump where they can cause fairly rapid wear.

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continued from page 13

along the bar by means of thermocouples. Rapid cooling favored nodule formation, but the effect of the cooling rate decreased with increase in magnesium content. No relation between nodule formation and pouring temperature or maximum heating temperature was observed. Results of the investigation support the belief that nodular graphite is formed in the melt during solidification, and that patches of graphite are produced after solidification by decomposition of carbides.

Nitrogen Brittleness

Results of fracturing V-notch steel specimens in Charpy impact tests indicate that increased nitrogen, if present as aluminum nitride, improves the low-temperature notch-toughness—lowers the temperature at which brittleness appears—in the steels studied. But nitrogen in the form of nitrides of iron or manganese is apparently detrimental from the same standpoint. The study was conducted by G. W. Geil, N. L. Carwile and T. G. Digges of the Thermal Metallurgy Laboratory.

The samples studied at NBS were of 0.3% carbon steels containing 0.9 or 1.6 manganese, 0.2 to 0.3% silicon, and variable nitrogen. Included was one aluminum-treated series. Notched specimens were fractured in impact at temperatures ranging from 320 to 212 F. The aluminum-treated steels tested showed much better low-temperature notch-toughness than the steels not so treated; transition temperatures, at which behavior changed from ductile to brittle, were approximately 54 to 90 F lower for the aluminum-treated specimens. Transition temperatures ranged from about 50 to 60 F for the non-aluminum-treated steels. In the latter the nitrogen was present as aluminum nitride, and transition temperatures decreased with increasing aluminum nitride content.

Stress Corrosion

Although the problem is an important one, much remains to be learned about the mechanism of stress-corrosion cracking. A continuing investigation conducted by Hugh L. Logan of the corrosion section now provides new data on some of the mechanical and electrochemical phenomena involved.

To get a better understanding of

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the forces at work in stress corrosion, the investigators measured electrochemical potentials of five alloys in normal film-covered and film-free conditions, both stressed and unstressed. Specimens were immersed in a suitable electrolyte, and potentials were determined using a calomel reference electrode of the saturated potassium chloride type.

Studied were an aluminum alloy, a magnesium alloy, two brasses, a low-carbon steel, and a stainless steel. Potentials were measured first for unstressed specimens having normal thin oxide films resulting from ordinary atmospheric exposure. Potentials were then measured for the same specimens after the filmed surfaces had been removed by abrasion with metallographic polishing paper. The abrading was done in an inert-gas (argon) atmosphere in a dry box, and the potentials were measured without removing the abraded specimen from this atmosphere. Each metal studied was more cathodic (more positive) in the normal film-coated form than in the abraded form, by amounts ranging from approximately 0.12 to 0.76 v.

The electrochemical solution potentials of the same alloys, in the normal film-covered conditions, were then measured with stress applied. It was postulated that, when tension is initially applied to a metal, small breaks develop in the protective film, giving corrosion a chance to get started before a fresh film can form. If the electrochemical potential of the unprotected area alone could be measured, it would presumably be roughly the same as that of a film-free surface.

This measurement problem was solved by coating an entire notched specimen with a non-conducting waterproof lacquer at the root of the notch. With specimens thus prepared, the only potential being measured was that of the narrow band of metal at the root of the notch where the stress was concentrated. With fairly rapid application of stress, the film-free area then became a substantial fraction of the total non-lacquer-covered area and the potential became more negative as the stress was increased. If the stress was held constant for some time, the solution potential generally reverted quickly to that of the unstressed metal. If the stress was increased rapidly, how-

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ever, the measured potential tended to approximate that of a film-free surface as the point of fracture was reached.

Determination of Copper

To conserve the supply of expensive and scarce alloying metals, many of the high-strength structural steels now being prepared for compliance to special or national emergency specifications are designed to utilize the alloy content of the scrap used in the steel-making process. This requires rapid methods of analysis so that the composition of the steel bath can be determined and necessary adjustments in composition and treatment can be planned during the melting period.

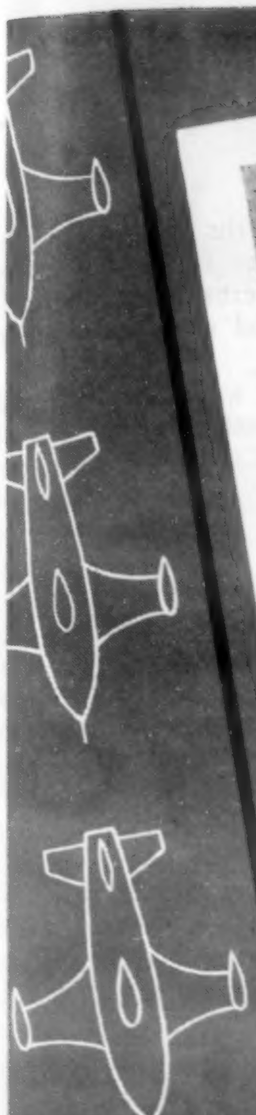
Though a number of accurate chemical methods are available for the determination of copper in steel, a rapid, one-step procedure specifically designed for the determination of copper in alloy steel has been lacking. This need now appears to have been met by a photometric method developed recently by J. L. Hague, E. D. Brown and H. A. Bright.

The reliability and accuracy of the method were checked by making a number of determinations on various standard samples of iron and steel. An accuracy of the order of 0.001% of copper was indicated for samples containing less than 0.05% of the element. All average values obtained for samples containing from 0.5 to 0.25% of copper were within 0.005% of the certified value.

The fact that the nickel content of the sample does not interfere in the analysis constitutes an additional advantage of the new procedure, for many of the present-day copper-bearing steels also require the presence of nickel in the alloy. Stainless and corrosion resisting steel, nickel-base casting alloys, and tool steel can be analyzed for copper content as easily as carbon steel.

Plexiglas Tested as Fillings for Teeth

The Air Force Technical Data Digest has announced that Plexiglas is now being studied for teeth fillings. The fillings come in many different



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tints to match the patient's teeth. Sable-hair brushes are used to apply them, as an alternative to the old-fashioned method of grinding them into the cavity.

Plastic fillings were first developed by German scientists on the eve of World War II. Civilian dentists have been trying them out for several years. But they pose a number of special problems for military dentists. Specifically, the Air Force wants to know how they are affected by extremes of altitude, temperature and humidity encountered in flight, and how they stand up under climates ranging from arctic ice fields to tropical jungles and deserts.

Twenty-five air bases scattered over the world have been selected for a thorough study of the fillings that may last three years or longer. Dental officers will observe how the plastics behave under a wide range of climatic conditions, and will report their findings to the School of Aviation Medicine which is supervising the research program. If plastics do the job, they will replace expensive metals like gold and silver and the silicate pastes now used for fillings. The advantages of plastics, aside from their colors blended to match the teeth, are their extreme toughness and the fact that they do not dissolve in the fluids secreted by the mouth.

A new, 20-page booklet, "How and Where to Specify Stainless Steel in Architecture," has just been published by the Committee of Stainless Steel Producers, American Iron and Steel Institute, 350 Fifth Ave., New York.

Welding Conference Papers Presented in Detroit

The third annual Welding Conference was held in Detroit Apr. 16-18. One session covered quality control, with papers outlining the history of government specifications and their impact on industry at the present time. Another meeting heard papers on resistance welding instru-

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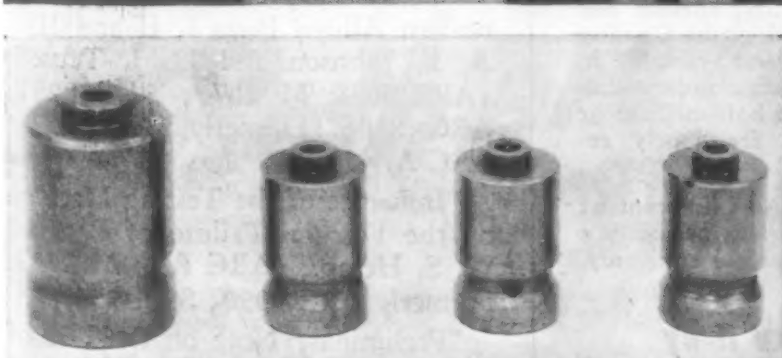

Unretouched photographs of precision parts quenched from a carbo-nitriding furnace in Park Triple A Quench Oil. From left to right are parts quenched the first day, 30 days later, 60 days later, and 90 days later. Bright and clean after over 3 months use with no indication of reduction of surface cleanliness.

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Now more than ever you will need Park Triple A Quench Oil . . . with steels of critical hardenability due to lean alloy content and parts manufactured under government contracts, you can't afford costly rejects due to rigid inspection. Get the most from your quench oil — get Park Triple A Quench Oil today and save on critical material and expensive rejects. Send for Bulletin No. F-8 today, for complete information.

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mentation. A third meeting covered power supplies for resistance welding machines. Resistance welding, with particular reference to up and down slope, a new three-phase welding system for aluminum, and the problems of aircraft spot welding, was the subject of another session.

On the subject of arc welding, two sessions were held. The first was on fundamental arc. The second was on practical arc welding, with papers on the consumable electrode arc in inert gas, an arc welding process for small aluminum wires, and qualitative instrumentation for d.c. arc welding.

NACA Publishes Research Abstracts

The National Advisory Committee for Aeronautics recently published reports on a number of research projects of interest to materials engineers. Copies of these reports are available from the NACA, 1724 F St., N. W., Washington 25, D. C. The following reports are available:

"The Effect of Current Variation on the Out-of-Balance of Strain Gauge Bridges." J. B. B. Owen. (ARC R & M 2497; ARC 10, 456. Formerly RAE Tech. Note SME 389.)

"Creep Tests on Some Cast Magnesium Alloys. Parts I, II and III." A. E. Johnson and H. J. Tapsell. (ARC R & M 2675; ARC 8281; ARC 8306. Formerly ARC 7595; ARC A. 459.)

"Influence of the Testing Machine on the Flexural Failure of Panels." W. S. Hemp. (ARC R & M 2539. Formerly ARC 9090; Strut 953.)

"Preliminary Note on the Use of Light Alloys Having High Values of the Modulus but Low Proof Stresses." H. L. Cox. (ARC R & M 2488; ARC 10, 236).

"The Effect of Grain Direction on the Mechanical Properties of Light Alloy Extrusions." Compiled by D. M. McElhinney. (MOS S & TM 14/15; Metropolitan-Armstrongs, Ltd., Weybridge. VTO/M/208.)

"Diffusion of Chromium in Alpha Cobalt-Chromium Solid Solutions." John W. Weeton. (NACA Rept. 1023. Formerly TN 2218.)

"Direct-Reading Design Charts for 75S-T6 Aluminum-Alloy Flat Com-

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pression Panels Having Longitudinal Extruded Z-Section Stiffeners." William A. Hickman and Norris F. Dow. (NACA TN 2435.)

"Development of Aluminum Alloys Having a High Young's Modulus." G. Meikle, J. Thompson and M. E. Whillans. (RAE Tech. Note Met. 149.)

"The Mixing of Casein Glues." P. M. C. Lacey. (Forest Products Research Lab., AMP 20/2.)

"The Deformation of Silver Wire at High Temperature." A. P. Greenough. (RAE Tech. Note Met. 151.)

Nickel Conservation Research Announced by Alloy Casting Institute

Conservation of vitally-needed nickel and chromium in heat resistant castings is the objective of important research just announced by the Alloy Casting Institute of Mineola, N. Y. Conducted at the Battelle Memorial Institute, research has been concentrated on developing a heat resistant material of lower alloy content than the high nickel alloys frequently used in 900 to 1400 F service. From knowledge of the iron-chromium-nickel alloys system and field experience, casting metallurgists selected an alloy containing 21 chromium and 9% nickel, designated as the HF type, as the material most likely to provide the combination of strength and corrosion resistance required for "intermediate temperature" (900 to 1400 F) service. Tests to date indicate that this alloy offers a promising solution to the requirements of such service.

Several years ago it was recognized that increased use of industrial processes operating in the 900 to 1400 F temperature range would create a demand for a somewhat lower alloyed material than the grades normally employed at higher temperatures. A limited alloy development study was authorized by the Alloy Casting Institute as part of the broad high temperature research program sponsored at Battelle for many years by the national organization of high alloy foundries. But when the post-Korea rearmament program rapidly brought about a shortage in the

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nickel supply, this added incentive caused the project to be given prime consideration, and intensive work was started in October 1950.

By June 1951 the nickel shortage became so acute that the National Production Authority started a program of "downgrading" alloys. This was formalized for heat resistant materials by order M-80, Schedule C, issued last December. The order places maximum limits on the nickel and nickel-chromium contents permitted for various temperature zones. For certain furnace parts and for oil refinery, synthetic rubber processing, cement mill and power boiler equipment in the intermediate temperature zone, the order limits maximum nickel content to 11%. Thus, alloys of the HF composition are the maximum permitted by the order for such uses.

The Battelle research team, under the supervision of J. H. Jackson, is now investigating a series of 14 compositions within the HF alloy specification range, to determine which compositions will offer optimum mechanical properties at elevated temperatures. If the present research on HF alloy continues favorable, then user should be able to substitute this grade in many intermediate temperature applications for materials containing from 30 to 100% more nickel, thereby freeing supplies of this vital element for higher temperature applications, where its use is indispensable.

The HF grade probably would have been investigated for this use a long time ago, except for the mistaken assumption that its properties in the 900 to 1400 F range are markedly inferior to the higher alloy materials now used. This incorrect idea doubtless arose from the fact that the wrought stainless steels containing about 18 chromium and 8% nickel have considerably less high temperature strength than the cast alloys of the 25 chromium-12% nickel and the 35 nickel-15% chromium types. However, this is not true in cast alloys, since the latitude of compositions possible in cast alloys allows use of chemical ranges unsuited to wrought alloy production. Tests now being made indicate the cast HF material to have strength properties comparable to higher alloyed cast grades at these intermediate temperatures.

This development is a striking il-

Turbine Ring
Glass Mold
CARBONEERING
by Speer

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lustration of the fact that the same nominal composition in wrought and cast alloys does not mean that mechanical properties of each material are the same—frequently, they are quite different. This situation points up the necessity for using the ACI alloy designations in ordering castings, rather than the AISI type numbers (302, 304, etc.) which are associated with wrought materials only.

Tin-Zinc Plate Protects Steel Bolts in Aluminum Structures

An 82-20 tin-zinc alloy plate is the best protection for steel bolts used in aluminum structures, according to tests conducted at the Fulmer Research Institute in England and reported by the Tin Research Institute.

Laboratory and field tests were run on sherardized, zinc plated, black oxide finished, cadmium plated, phosphate coated and tin-zinc alloy plates steel bolts. One set of specimens of each coat was exposed to one of the following: 3% salt spray; humid SO_2 atmosphere; marine atmosphere; industrial atmosphere. In every case the zinc-tin alloy coatings protected the bolts and gave rise to a minimum amount of corrosion of the aluminum. Zinc coatings gave the next best performance, protecting the steel with slight attack of the aluminum, although more corrosion products were formed and the bolts were less easy to remove. None of the other coatings gave full protection.

Deadline Nears for Certification of Induction and Dielectric Equipment

The National Electrical Manufacturers Association wishes to call to the attention of all users of induction and dielectric heating equipment, particularly those whose equipment was manufactured prior to June 15, 1947, the provisions of the FCC Rules and Regulations, Part 18, relating to radiation and communication interference from industrial induction and dielectric heating equipment.

In essence, the rules require certi-

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fication, on or before June 30, 1952, of compliance with certain minimum radiation requirements for all equipment installed or manufactured prior to July 1, 1947. A period of five years was allowed by the Commission for users of uncertified equipment to properly check and obtain certification of their equipment. The deadline date of June 30, 1952 is rapidly approaching, and all such users of uncertified equipment should take due notice and take steps to comply with the Commission's Rules.

It is suggested that users of older type equipment contact the manufacturer of the equipment or a consulting engineer for guidance in complying with the rules. A complete copy of the FCC Part 18, Rules and Regulations Relating to Industrial, Scientific and Medical Service, may be obtained from the United States Government Printing Office, Washington, D. C.

ASTM Holds Symposium on Testing Metal Powders and Sinterings

Committee B-9 of the American Society of Testing Materials held a symposium on methods of testing metal powders and metal powder parts at the Cleveland meeting of the Society in March.

This symposium consisted of seven papers presented in a morning and an afternoon session. The morning session was devoted to methods of testing metal powder products and the afternoon session to metal powders. F. V. Lenel, Rensselaer Polytechnic Institute, headed the Symposium Committee.

The first paper, "Quality Control of Metal Powder Gears," was by W. A. Hinkle, Quality Control Engineer, Trenton Works, General Electric Co. The automatic washing machine built at the Trenton plant uses a train of four gears which were originally designed to be machined from a foundry product. Instead, the company is using copper infiltrated metal powder gears, which it purchases. Because of this new material, the question arose whether the dimensional tolerances required for satisfactory running of the gears and a

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9-M-39

W-S "COMPLETELINE"—SHORTEST DISTANCE FROM PRODUCTION TO PROFIT

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high enough shear strength of the gear teeth to withstand the loads applied to them could be maintained in commercial production. By means of statistical analysis continued over a one-year period, Mr. Hinkle was able to show that the control of both dimensional tolerances and of shear strength in these gears was satisfactory.

Captain John D. Dale, of Frankford Arsenal, presented a paper on "Methods and Devices for Testing Sintered Iron Rotating Bands." These bands had been developed during the recent World War by the German forces principally to save critically short copper. Intensive studies led to the conclusion that they may be not only a satisfactory substitute, but even superior to the conventional driving bands made of gilding metal. The Germans found it necessary to specify in detail the raw material and the processing steps in order to obtain a satisfactory product. In contrast, the efforts of the Army Ordnance Corps are directed towards developing methods of testing the finished products which would insure satisfactory performance of the band in ballistic tests. Captain Dale described in detail both the German and the American methods for testing these bands.

The paper on "Porous Stainless Steel Compacts for Transpiration Cooling" by F. V. Lenel and O. W. Reen, Rensselaer Polytechnic Institute, was presented by Mr. Reen. Transpiration cooling is a particularly effective method of cooling components in jet and rocket engines in which the coolant, passing through the porous component in a direction opposite to the heat flow, gradually increases in temperature and finally forms a protective layer on the surface which is exposed to heat. When transpiration cooling is to be used in turbine blades for turbo jet and turbo propeller engines, the porous material must not only have sufficient permeability so that the desired amount of coolant will pass through them, but must also withstand the centrifugal stresses imposed upon the blades at their operating temperature. The paper described methods for testing the permeability, the room temperature tensile strength, and the stress to rupture for various times at 1100 F, for compacted and sintered specimens. Data on the relationship be-

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tween permeability and strength properties of compacts made of various stainless steel alloy powders were presented.

The paper by A. D. Stevens and J. C. Redmond, of Kennametal, Inc., on "Methods of Testing Cemented Carbide Compositions" discussed such methods as chemical analysis, x-ray diffraction analysis, density, Rockwell A hardness, modulus of rupture, and photomicrographic examination as applied to cemented carbides for use in tool materials. Most of these methods are now under consideration by Committee B-9 for possible standardization. A proposed method for determining the type and amount of porosity by microphotography is to be presented to the Society shortly for publication.

All three papers of the afternoon session were concerned with methods for measuring the particle size and particle size distribution of metal powders. R. P. Seelig, the American Electro Metal Corp., presented a literature survey entitled "Particle Size Determination in Metal Powders." Starting with a discussion of the definition of particle size in powders, he covered methods of sieving, visual observation under the optical and electron microscope, sedimentation and elutriation methods based upon Stokes' law, and methods based on the determination of specific surface, such as the pressure drop of a fluid passing through a bed of powder, turbidimetric and gas adsorption methods.

P. S. Roller discussed "Metal Powder Size Determination by the Roller Air Analyzer." This instrument is widely used in the metal powder industry. Its method of size determination is based upon the elutriation of a metal powder by a stream of air. The author presented data which will be of particular use in determining the end point in particle size determination and in evaluating the method for use with irregularly shaped particles.

The last paper, "Some Experiences in Specific Surface Measurement by Low Temperature Gas Adsorption," was by J. B. Haertlein and J. F. Sachse, Metals Disintegrating Co. Gas adsorption methods had been applied previously, principally to catalysts and to pigments. Mr. Haertlein showed that the method is also applicable to metal powders, giving

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comparative data with the Roller air analyzer and Fisher subsieve sizer methods. Particularly for very fine powders having internal porosity, the adsorption method is able to detect significant differences in specific surface which cannot be found by other methods.

Thermal indicators made of paper have been developed by the Army Quartermaster Corps. They are capable of instant temperature readings from 115 to 500 F. The thermometer consists of white pigment coating on black papers. The coating can be designed to melt at any definite temperature, leaving a black background. The indicators can be used by colorblind people, and commercial production should bring cost down to a few cents each.

World's Largest Water-Cooled Mold Installed

What is claimed to be the world's largest water-cooled slab mold, built by the Machine Div. of Torrington Manufacturing Co., is now being installed in the New Bedford, Mass., plant of Revere Copper and Brass. Larger cakes can be cast than by previous methods, so that economies will be effected in the casting and processing of brass. The mold weighs over 40,000 lb and stands 8 ft high. A Muntz metal slab weighing 8,000 lb can be cast in the mold, which is so designed that eventually it can cast a slab 10 in. thick, weighing 10,000 lb.

An outstanding feature is the intricate water cooling system. A honeycomb compartment designed for maximum cooling power lies behind each of the mold's 3-in. copper plates. As the mold is filled with molten metal, water flows continuously through these compartments. Up to 4,000 gal of water per minute cool the mold and carry heat off from the cast bar. The water itself rises only 10 F approximately in its passage through the mold.

In overall dimensions the mold is

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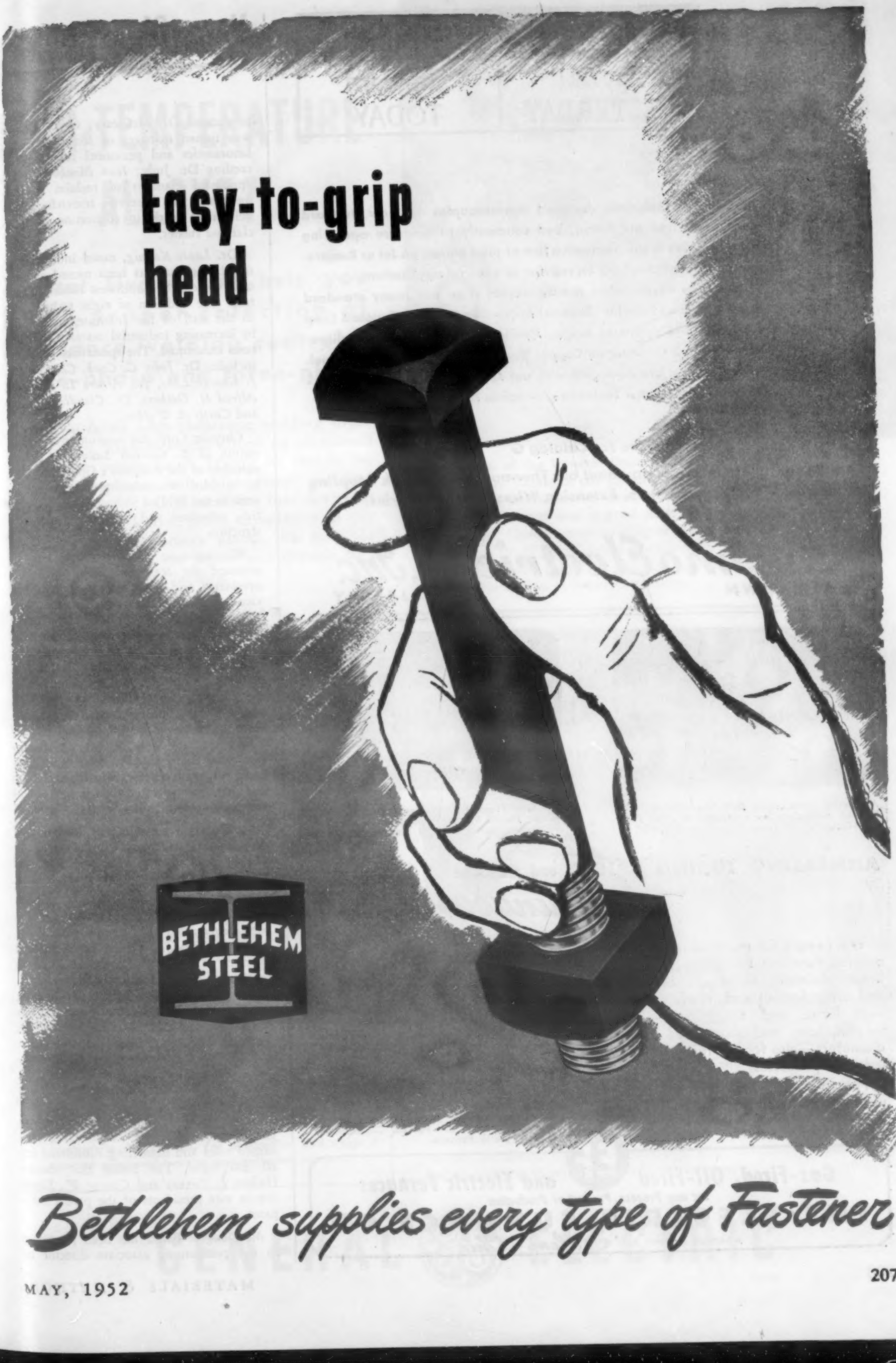
8 ft wide, $4\frac{1}{2}$ ft thick, and 8 ft high. Shipping weight was 42,000 lb, the copper plates alone tipped the scales at 10,500 lb. The mold cavity size is 50 in. wide, 8 in. thick and 6 ft high.

News of Engineers

United Lacquer Manufacturing Co. has announced the appointment of *William E. Knappman* as technical director. In this capacity, Mr. Knappman will direct research activities in the company's development laboratory.

The appointment of *Lowell T. Smith* as assistant metallurgical engineer of the Metals Dept., Research and Development Div., Olin Industries, Inc. has been announced by the company. Also announed was the appointment of general managers of the five newly created integrated operating divisions of the company: *M. W. Acker*, Olin director and vice president, has been named general manager of the Metal Div., with headquarters at East Alton, Ill.; *W. C. Schade* has been elected general manager of the Arms and Ammunition Div., with headquarters at New Haven, Conn.; *W. S. Allen* will manage the Electrical Div. with headquarters at New Haven; *N. A. Hamilton* has been made general manager of the Explosives Div., with headquarters in East Alton; and *O. E. Nelson* will manage the Export Div., with headquarters in New Haven. *George L. Dawson*, who has been regional manager of the company plants in New Haven, has been appointed staff assistant to the executive vice president. The company has also annouced the appointment of Dr. *Fred Olsen* as vice president for research and development.

Willard deCamp Crater, Jr. has been appointed chief of the thermoplastics section, Chemical Div., National Production Authority in Washington. Mr. Crater, who is the assistant manager of vinyl sales for the Naugatuck Chemical Div., U. S. Rubber Co., has been given a leave of absence by the company in order to assume his government post. Four major organizational changes in the Research and Development Dept., Naugatuck Chemical Div., have also been announced by the company. Dr. *C. D. McCleary*, formerly manager of process development, has been named manager of basic research which comprises the organic research formerly handled by Dr. *D. L. Schoene*, recently appointed manager of plastics development; Dr. *J. N. Judy*, formerly manager of technical service laboratories, was appointed manager of process development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to succeed Dr. McCleary; *G. G. Durbin* was named manager of technical service laboratories and personnel relations succeeding Dr. Judy; *Ivan Mankowich* was appointed manager of reclaim development and will supervise research and development work in connection with reclaimed rubber.

Dr. *Louis Koenig*, noted industrial research chemist, has been named an associate director of Southwest Research Institute. The addition of eight technologists to the staff of the Institute, necessitated by increasing industrial research, has also been announced. The specialists appointed include: Dr. *John C. Cook, Chi-Sun Lin, J. George Loos, Jr., Arturo L. Martinez, Alfred H. Oelkers*, Dr. *Claudia P. Ritter* and *Curtis A. Walker*.

Chrysler Corp. has announced the resignation of *S. Gordon Saunders*, general manager of the company's Cycleweld Div., to establish a consulting service of his own in the field of industrial paints, plastics, adhesives and sandwich panel construction.

Westinghouse Electric Corp. has announced the reassignment of two vice presidents and the election of two new vice presidents. Reassigned were *Tom Turner* and *T. I. Phillips*. Mr. Turner, who had been vice president in charge of industrial relations, is now vice president in charge of the Motor and Control Div. at Buffalo; and Mr. Phillips, who headed the company's East Pittsburgh divisions, succeeds Mr. Turner as staff vice president in charge of manufacturing. Elected vice presidents were *Robert D. Blasier* and *John E. Payne*. Mr. Blasier will assume responsibility for industrial relations and Mr. Payne will take charge of the company's central sales district.

At the regular meeting of the board of directors of Macwhyte Co. *George C. Wilder* was elected vice president and assistant general manager of the firm.

Promotion of six key executives of Minnesota Mining & Manufacturing Co. has been announced by company officials. *Louis F. Weyand*, a vice president and member of the board, was promoted to executive vice president; *Robert W. Young*, president of Minnesota Mining & Manufacturing International Co., a wholly owned 3M subsidiary handling foreign trade, was named to the chairmanship of the board; *Clarence B. Sampair*, vice president of 3M International, succeeded Mr. Young as president in addition to retaining his former post; vice president *John A. Borden*, general manager of the Cellophane Tape Div., was named sales and marketing consultant for all 3M tapes. The board also elected *Hubert J. Tierney* and *George W. Swenson* as vice presidents of the parent company.

M. Douglas Banus has been promoted to the position of associate director of

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research in charge of the Chemical Research Laboratories at Metal Hydrides, Inc., and *Robert W. Bragdon* has been promoted to the position of assistant director of research for the company.

William P. Drake, vice president of the Pennsylvania Salt Manufacturing Co., has been named director of the Rubber, Chemicals and Drugs Div., Office of Price Stabilization. The new director succeeds *Thomas H. McCormack*, who is returning to his duties as director of sales of the Grasselli Chemical Div., E. I. du Pont de Nemours & Co., Inc.

Reinforced Plastic Consultants & Engineers has announced the appointment of *Samuel S. Oleesky* as chief engineer, Research and Development Div.

James P. Growdon, chief hydraulic engineer for Aluminum Co. of America since 1938, will become an engineering consultant on hydraulic and related engineering problems for ALCOA. *B. J. Fletcher*, assistant chief hydraulic engineer, will succeed Mr. Growdon.

Henry A. Mullen, manager of the Resistance Welding Div., Ampco Metal, Inc., has recently been appointed a member of the original Advisory Committee of the Resistance Welder Electrode Manufacturers Industry.

The following recent changes in Watson-Stillman executive positions have been announced: *R. S. Sweeney*, vice president and treasurer, has been elected a director; *James W. West, Jr.*, a director of the company, has been appointed assistant to the president; *A. B. Diss* has been named vice president in charge of manufacturing; *R. W. Dinzl* has been appointed consulting engineer; *Adolph deMatteo* has been named chief engineer; *R. W. Schreck* has been appointed general manager of Sales, Hydraulic Div.; *Jackson Kemper* has been named general manager of sales, Distributor Products Div.; and *Herbert E. Elliott* has been appointed sales manager, Hydraulic Div.

C. Dale Dickinson, an Allis-Chalmers research engineer, has been awarded an Allis-Chalmers fellowship for 12 months of residence study for a doctor of philosophy degree in metallurgical engineering.

Henry N. Shoiket has been named head of the Mechanical Engineering Dept., Sam Tour & Co., according to a recent company statement.

Dr. *Donald J. McPherson* and *Harold D. Kessler*, research metallurgists in the Metals Dept. at Armour Research Foundation, Illinois Institute of Technology, have been promoted to supervisors. Dr. McPherson will head the newly formed Physical Metallurgy Section and Mr. Kessler will be supervisor of the Nonferrous Metallurgy Section. Dr. *John Theodore Rettaliata*, vice president and dean of engineering at the Institute, was named president. He succeeds Dr. *Henry T.*

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Heald, who will leave Chicago to become chancellor of New York University.

Jack G. Copeland, Jr., has been named works manager of Hercules Powder Co.'s plant at Carthage, Mo., according to a recent company announcement. Mr. Copeland has been assistant works manager of the company's dynamite, ammonia and acid plant at Hercules, Calif., since 1947.

Homestead Valve Manufacturing Co. has appointed *John W. Force* as vice president in charge of engineering.

Appointment of *Paul A. Metz, Jr.*, to the post of chief chemist of the New Bedford plant of Goodyear Tire & Rubber Co. has been announced.

George A. Fyrberg has been named production manager of Norton Co.'s Abrasive Div., succeeding *Harold C. Dunbar*, who is retiring after 39 years with the company.

American Wheelabrator & Equipment Corp. has announced the promotion of *Andrew B. Stevens* to the position of assistant factory manager.

Stephen A. Keller has been named general manager of the Valve Div. of Minneapolis-Honeywell Regulator Co. He succeeds *James H. Binger*, who will continue as vice president of the division.

Appointment of *E. E. Wesselhoff* as assistant chief engineer, Morse Chain Co., has been announced.

Irving B. Remsen, Jr., formerly a division engineer of American Viscose Corp., has joined the headquarters engineering staff of Hall Laboratories, Inc., for work as technical consultant on waste water problems in the industrial, municipal and utilities fields.

Rust Furnace Co. has appointed *O. D. Rice*, chief engineer, to the position of manager of operations. *H. Hayward Dinneen* was named to succeed Mr. Rice.

The creation of a New Products Dept. and the appointment of *John P. Emmett* as its head have been announced by Detrex Corp.

Ray L. Morrison, executive vice president of DeVilbiss Co., has been elected president of the Northwestern Ohio Industrial Council.

Robert G. Hess, formerly assistant to the executive vice president of the New York Air Brake Co., has recently been elected president and a member of the board of Kinney Manufacturing Co.

William P. Barnes, Jr., has joined the staff of mechanical engineers working on combustion projects at the Atlantic Research Corp. Previous to his appointment, Mr. Barnes served in the Machine Design Div., Goodyear Tire and Rubber Co., and has also been with E. I. du Pont de Nemours & Co., Inc. and the Hercules Powder Co.

Several appointments and changes have

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been announced by General Electric Co. *Carl A. Salmonsen* has been appointed general manager of the company's newly formed Industry Control Dept.; *William L. Rodich* has been promoted to general manager of the Laminated and Insulating Products Dept., Chemical Div.; *Jesse A. Gardenier,* production manager of the Large Motor and Generator Dept., retired after serving more than 50 years with the company; *Thomas Sproule* has been named manager of manufacturing of the company's Welding Dept. in Fitchburg, Mass. Decentralization of the company's Transformer and Allied Products Div. has resulted in the establishment of three independent business operations and a Laboratory Engineering Dept. *William S. Ginn* has been named general manager of the Power Transformer Dept.; *Raymond W. Smith* has been named general manager of the Distribution Transformer Dept.; *Alfred W. Hough* will become general manager of the Capacitor Dept.; and Dr. *Karl B. McEachron* has been named manager of the Laboratory-Engineering Dept.

Four promotions among management personnel of Precision Castings Co., Inc., were announced by the company. *William J. During,* previously vice president and general manager, has been promoted to executive vice president. Advanced to vice presidents were *J. J. Punke, Albert Lintel* and *Ross W. Castle.*

International Telephone and Telegraph Corp. has announced the death of *Jacob S. Jammer,* vice president and director of International Standard Electric Corp.

The death of Dr. *Edward G. Mahin,* retired head of the Dept. of Metallurgy of Notre Dame, has been announced.

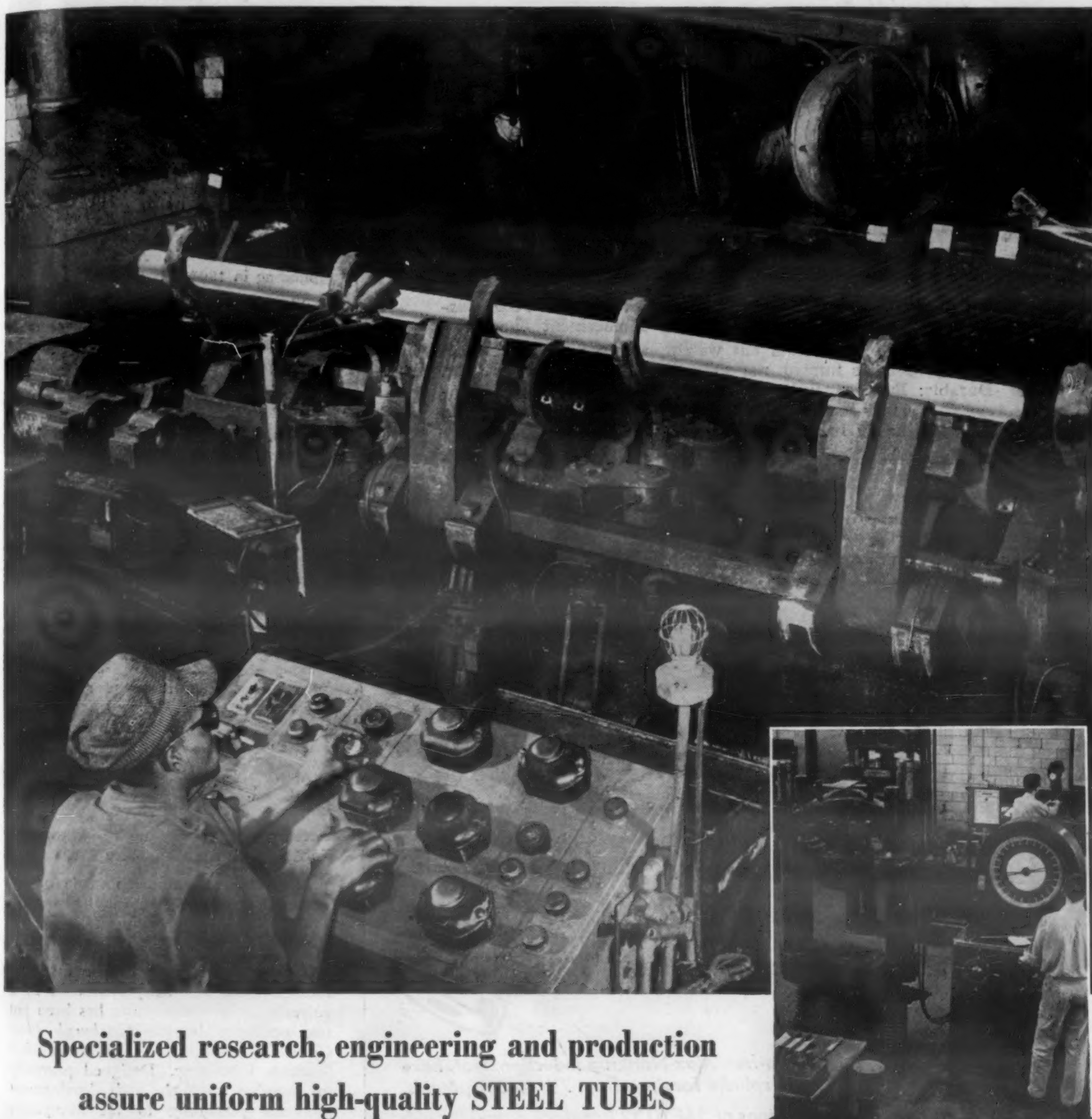
Parker-Kalon Corp. has announced the death of *Heyman Rosenberg,* founder and director of the company.

News of Companies

National Research Corp. has announced the activation of a wholly-owned subsidiary, *Vacuum Metals Corp.,* with offices and facilities in Cambridge, Mass.

An additional manufacturing unit is nearing completion at the Fairfield, Ala. plant of *Harbison-Walker Refractories Co.* The new unit is expected to increase the company's production of silica brick by 50%.

Electrochemical Industries, Inc., Worcester, Mass., has announced that it has been designated as manufacturer's agent



Globe's Physical Testing Laboratory — one of the seven different research and testing labs in Globe's House of Science.

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by the *Bersworth Chemical Co.*, Framingham, Mass., to handle the sales and distribution in the metal finishing and allied fields of the wide variety of organic compounds known as Versenes.

Uddeholm Co. of America has announced the opening of a branch office and warehouse at 5037 Anaheim-Telegraph Road, Los Angeles.

Nice Ball Bearing Co. is currently celebrating the Golden Anniversary of its founding in 1902.

Plans for building new facilities for the production of electrolytic manganese at the Marietta, Ohio, plant of *Electro-Metallurgical Co.* were announced. About 6,000 tons a year are expected to be produced.

Completion of a new plant at Santa Clara, Calif., to manufacture butylated melamine and urea resins has been announced by *Monsanto Chemical Co.*

Completion of the new *Bjorksten Research Laboratories'* building at Madison, Wis., to house the Laboratories' enlarged Mining and Metallurgical Div. has been announced.

The entrance of *Doram Products, Inc.* into the coating product field has been announced. The newly-established company will specialize in the manufacture of coatings to be used in conjunction with the various metallizing processes, namely vacuum evaporation and silver spray.

Macro (Exploration Div. of Kennametal, Inc.) with a main plant at Latrobe, Pa., will build an ore dressing and electric smelting works on Kingsway at Port Coquitlam on a 20-acre site.

Announcement has been made of the opening of a new web coating research and development laboratory by *Industrial Ovens, Inc.*

What is believed to be the first preform molding laboratory sponsored by a polyester resin manufacturer has been put into operation by the *Pittsburgh Plate Glass Co.*, Paint Div., at its Milwaukee Research Laboratory. Designed primarily to expedite research and development problems pertaining to the company's series of polyester resins marketed under the trade name of Selectron, the new laboratory is also being used to find the solution to customer preforming problems in instances where the fabricator involved does not have the necessary equipment to thoroughly explore his own preforming techniques.

A $65,000,000 expansion program that is expected to increase *Kaiser Steel Corp.'s* pig iron output by 50% and raise steel ingot production by more than 11% has been announced.

Construction by *Corning Glass Works* of a new optical glass plant in Harrodsburg, Ky., has been announced. The new plant, which will employ about 250 per-

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sons, will contain 100,000 sq. ft. of floor space and is expected to be in operation by the end of the year.

The general offices of *Crucible Steel Co. of America* have been established in Pittsburgh, according to a recent announcement. Crucible's quarters in the Oliver building have been enlarged several times, and with this move, the number of people in the Pittsburgh office will be more than 200.

The Udylite Corp. will start construction on a research laboratory building on a 23-acre site on Hoover Ave., near Eight Mile Rd. The new building is the first unit of a long term building project which will eventually house all of the company's manufacturing and administrative operations.

Two fellowships in mechanical engineering at Stevens Institute of Technology will be awarded to outstanding candidates for an advanced degree by the *Celanese Corp. of America,* beginning with the school year 1952-1953. The stipend for each fellowship is $150 per month for nine or 12 months and remission of graduate tuition, fees and normal laboratory expenses.

According to a recent announcement, *Barber-Colman Co.* will purchase the principal assets of *Wheelco Instruments Co.*

Atlantic Steel Co. will construct a new half-million dollar warehouse and office building at the corner of Northside Drive and 14th St. for its Warehouse Div.

Worthington Pump and Machinery Corp. has announced the change of its corporate name to *Worthington Corp.*

Seattle Chain & Manufacturing Co. has announced the change of its corporate name to *Round Seattle Chain Corp.*

News of Societies

New developments in two phases of metallurgy will be reviewed in special courses in Surface Reactions in Flotation and Chemistry and Mechanics of Molding Materials to be given at the *Massachusetts Institute of Technology* during the summer of 1952. New developments in five phases of mechanical engineering will be emphasized in special courses in Metal Cutting, Internal Combustion Engines, Lubrication Engineering, Vibration, and Industrial Photo-elasticity, also to be given during the summer of 1952.

The removal of the executive offices of the *American Electroplaters' Society* from Jenkintown, Pa., to the American Bldg., 445 Broad St., Newark 2, N. J., has been announced.

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The summer laboratory course in Techniques and Applications of the Electron Microscope will be given from June 16 to June 28, 1952, by *Cornell University*, College of Engineering.

The first branch of the Scientific Research Society of America between Pennsylvania and the Pacific Coast has been established in Texas, in recognition of the work of the *Southwest Research Institute*. Dr. Charles A. Culver, dean of professional development at SwRI, was installed as the first president of the branch. Other officers elected were: Dr. John Loefer, research biologist of the Southwest Foundation for Research and Education, vice president; Dr. John C. Cook, SwRI physicist, secretary; and Fred Koebel, SwRI mechanical engineer, treasurer.

National medal awards for outstanding leadership in the steel casting industry were recently conferred at the 50th Anniversary meeting of the *Steel Founders' Society of America*. Honored with presentation of the Society's top award, the Lorenz Memorial Gold Medal, was James Suttie, vice president, American Steel Foundries. Award of the Society's Technical and Operating Gold Medal for 1951 was made to Luther A. Kleber, vice president in charge of manufacturing, General Steel Castings Corp. Harold H. Johnson, chief metallurgist, National Malleable and Steel Castings Co., received the annual Steel Foundry Facts award for excellence of material published in the Society's technical publication. Formal announcement was also made of the election of H. A. Forsberg, vice president, Continental Foundry & Machine Co., as president of the Society and the election of Carl F. Barchfeld, sales manager, The Commercial Steel Casting Co. as vice president.

Boston College has announced a special two weeks intensive course in Modern Industrial Spectrography from July 21 to Aug. 1, 1952.

The Penn State Chapter, *American Society for Metals*, has announced the selection of William Wetzel Sieg as the 1952 recipient of the David Ford McFarland Award. Mr. Sieg, president of the Titan Metal Manufacturing Co., received the award on the basis of his attainments in a metallurgical industry and outstanding work in civil affairs.

Leslie B. Bellamy, Detroit manager, Sterling Grinding Wheel Div., Cleveland Quarries Co., was elected president of the *American Society of Tool Engineers* for 1952-1953 at the Society's 20th annual meeting. Elected first vice president of the Society was Roger F. Waindle, director of research, The Nugent-Sand Co., Inc. Joseph P. Crosby, vice president, The LaPointe Machine Tool Co., was named 2nd vice president; and Dr. Harry B. Osborn, Jr., technical director, TOCCO Div., The Ohio Crankshaft Co., was named 3rd vice president.

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Meetings and Expositions

COPPER & BRASS RESEARCH ASSOCIATION, annual meeting. Hot Springs, Va. May 18-21, 1952.

NUCLEAR ENERGY CONFERENCE. East Lansing, Mich. May 20-21, 1952.

AMERICAN IRON & STEEL INSTITUTE, general meeting. New York. May 21-22, 1952.

AMERICAN SOCIETY FOR QUALITY CONTROL, annual convention. Syracuse. May 22-24, 1952.

SOCIETY OF AUTOMOTIVE ENGINEERS, summer meeting. Atlantic City, N. J. June 1-6, 1952.

AMERICAN GEAR MANUFACTURERS' ASSOCIATION, annual meeting. June 2-4, 1952.

INTERNATIONAL MECHANICAL ENGINEERING CONGRESS. Stockholm, Sweden. June 4-10, 1952.

CONFERENCE ON INDUSTRIAL RESEARCH. New York. June 9-13, 1952.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, semi-annual meeting. Cincinnati. June 15-19, 1952.

MALLEABLE FOUNDERS' SOCIETY, annual meeting. Hot Springs, Va. June 16-17, 1952.

AMERICAN ELECTROPLATERS' SOCIETY, annual meeting and industrial finishing exposition. Chicago. June 16-20, 1952.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Applied Mechanics Div. conference. State College, Pa. June 19-21, 1952.

ALLOY CASTING INSTITUTE, annual meeting. Hot Springs, Va. June 22-24, 1952.

AMERICAN SOCIETY FOR TESTING MATERIALS, annual meeting. New York. June 23-27, 1952.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Applied Mechanics Div., West Coast conference. Los Angeles. June 26-28, 1952.

CENTENNIAL OF ENGINEERING. Chicago. July 1-Sept. 30, 1952.

INTERNATIONAL TRADE FAIR. Chicago. Aug. 2-17, 1952.

SOCIETY OF AUTOMOTIVE ENGINEERS, West Coast meeting. San Francisco. Aug. 11-13, 1952.

AMERICAN STANDARDS ASSOCIATION, national standardization conference. Chicago. Sept. 8-10, 1952.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, fall meeting. Chicago. Sept. 8-11, 1952.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Instruments and Regulators Div. and INSTRUMENT SOCIETY OF AMERICA, exhibit and joint conference. Cleveland. Sept. 8-12, 1952.

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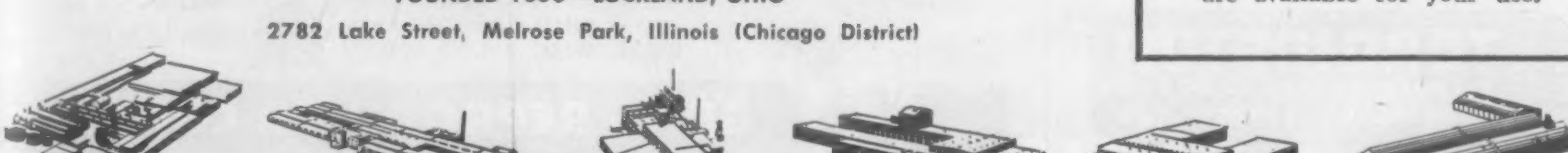

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BOOK REVIEWS

Powder Metallurgy

TREATISE ON POWDER METALLURGY—VOL. III. *By Claus G. Goetzel, Published by Interscience Publishers, Inc., New York 1, N. Y., 1952. Cloth, 6¼ by 9¼ in., 899 pages. Price $22.00.*

This third and final volume of "Treatise on Powder Metallurgy" is a classified and annotated bibliography on the subject of powder metallurgy. It is the most complete and comprehensive one published on this subject to date, and contains almost 12,000 literature and patent references.

The volume is divided into two parts, the first containing literature references and the second a patent bibliography. Each of these major parts is organized according to subject and follows closely the classifications in the first two volumes of the "Treatise". Each entry is annotated with several lines describing the reference. Also included is a comprehensive subject and name index.

Other New Books

1950 SUPPLEMENT TO SCREW-THREAD STANDARDS FOR FEDERAL SERVICES, 1944. *Published by U. S. Department of Commerce, Washington 25, D. C., 1951. Paper, 8 by 10¼ in., 113 pages. Price 50¢.* This 1950 Supplement to Handbook H28 (1944), Screw Thread Standards for Federal Services, replaces and augments the Supplement issued June 15, 1949. The approval of these standards by the Federal Departments represented on the Interdepartmental Screw Thread Committee makes them available for application to new designs and for acceptance of bolts, screws, nuts and other threaded products that conform to these standards.

ARC WELDING. *By Charles H. Zielke. Published by The Bruce Publishing Co., Milwaukee 1, Wis., 1952. Paper, 8¼ by 10¾ in., 63 pages. Price 80¢.* This book, based on the author's experience both as a welder and as an instructor of welding, was written in an attempt to help the student save time and effort and eliminate unnecessary trial and error.

PLASTICS MOLDING. *By John Delmonte. Published by John Wiley & Sons, Inc., New York 16, N. Y., 1952. Cloth, 6¼ by 9¼ in., 493 pages. Price $9.00.* A carefully planned analysis of the plastics molding industry and its equipment, as well as the principles and accessories that permit a molder to attain a high degree of versatility.